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SEP 76 J G PECK, B L FISHER

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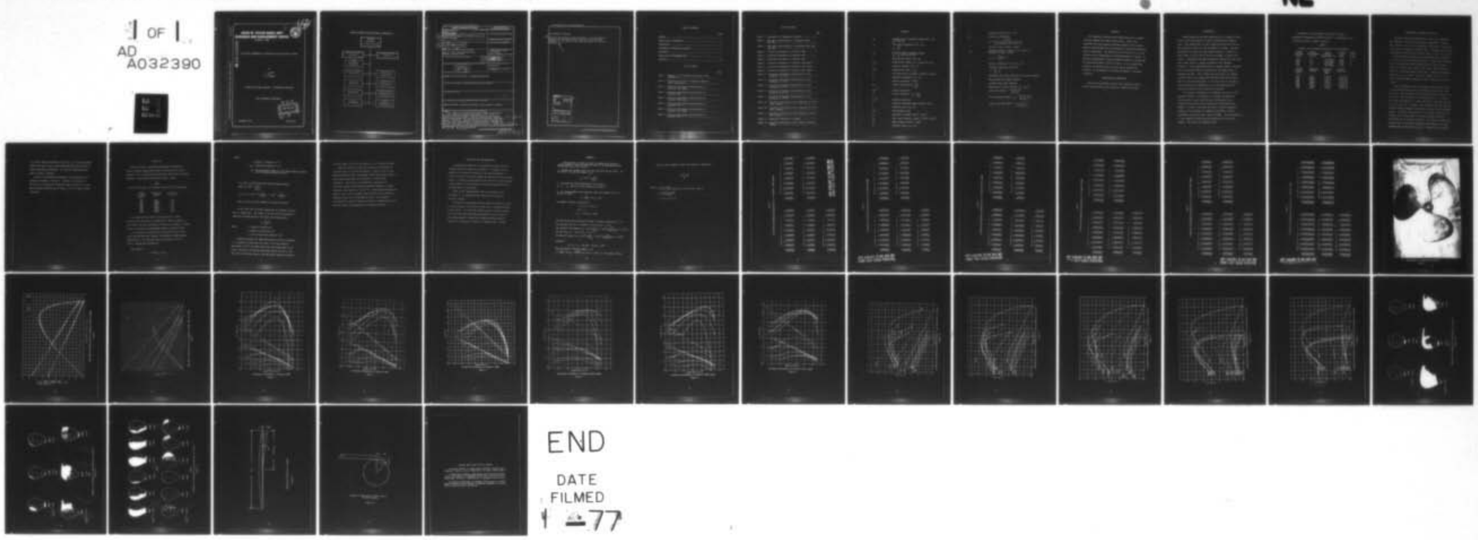

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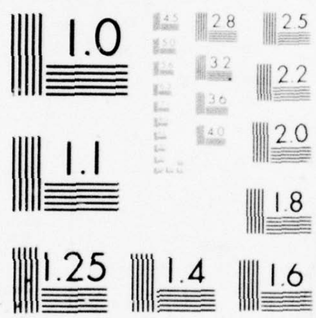

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CAVITATION PERFORMANCE OF PROPELLERS WITH AND WITHOUT CUPPING

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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

AD A032390

CAVITATION PERFORMANCE OF PROPELLERS WITH AND WITHOUT CUPPING

by

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and
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SHIP PERFORMANCE DEPARTMENT

September 1976

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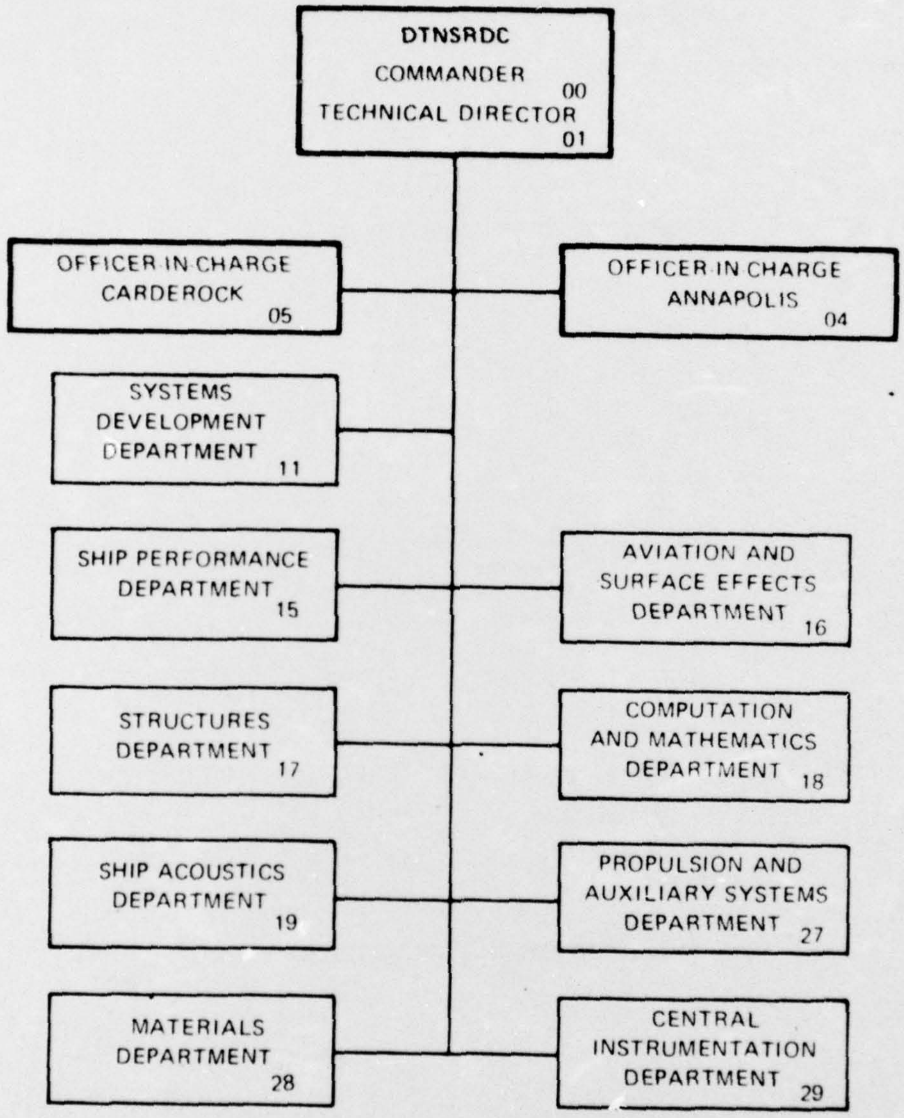

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Four commercial propellers were characterized over a range of cavitation numbers and advance coefficients. Three of the propellers were then cupped to different degrees on the trailing edge and characterized over the same range of cavitation numbers and advance coefficients. The results show an increase in K_T, K_Q, and effective pitch corresponding to increasing degrees of cupping. An empirical relationship is derived between the amount of cupping and

K sub T, K sub Q,

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20. ABSTRACT (Continued)

the resulting increase in effective pitch. It is concluded that cupping is an effective means of correcting an underpitched propeller, at the expense of efficiency and danger of increased cavitation.

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NOTATION

A_E	Expanded area of propeller blades (ft^2), (m^2) A_E = EAR (A_o)
A_o	Disc area of propeller (ft^2), (m^2) $A_o = \frac{\pi D^2}{4}$
A_P	Projected area of propeller blades $A_P = A_E$ (1.067-0.229 P/D)
C	Blade section length (ft), (m)
$C_{0.7}$	Blade section length at 0.7 radius (ft), (m)
D	Propeller diameter (ft), (m)
EAR	Expanded area ratio A_E/A_o
g	Acceleration due to gravity (ft/sec^2), (m/sec^2)
h	Propeller submergence (ft), (m)
J	Advance coefficient $J=V/nD$
K_T	Thrust coefficient $K_T = \frac{T}{\rho n^2 D^4}$
K_T/J^2	Loading coefficient
K_Q	Torque coefficient $K_Q = \frac{Q}{\rho n^2 D^5}$
K_Q/J^3	Powering coefficient
n	Propeller rotational speed (rev/sec), (r/s)
P	Propeller pitch (ft), (m)
P/D	Pitch-diameter ratio
P_A	Atmospheric pressure (lb/ft^2), (N/m^2)
P_H	Static water pressure, $P_H=\rho gh$, (lb/ft^2), (N/m^2)
P_V	Vapor pressure (lb/ft^2), (N/m^2)
T	Propeller thrust (lb), (N)

Q	Propeller torque (lb/ft), (N·m)
Q_c	Torque load coefficient, $Q_c = \dfrac{2.55\ K_Q}{(J^2+4.84)(EAR)(1.067-0.229\ P/D)}$
v	Velocity of boat (ft/sec), (m/sec)
$v_{o.7}$	Resultant velocity of water at 0.7 radius of propeller (ft/sec), (m/sec) $v_{o.7}{}^2 = \dfrac{J^2+4.83}{J^2}\ v^2$
x	Amount of cupping at 0.7 R, (in), (m)
η	Propeller open water efficiency, $\eta = \dfrac{K_T}{K_Q}\ \dfrac{J}{2\pi}$
θ_A	Additional pitch angle required for new pitch, degrees
θ_n	New required pitch angle, degrees
θ_o	Original pitch angle, degrees
ρ	Mass Density of water ($\text{lb-sec}^2/\text{ft}^4$), ($K_g/m^3$)
σ	Cavitation number, $\sigma = \dfrac{P_A + P_H - P_V}{(1/2)\rho v^2}$
$\sigma_{0.7}$	Local cavitation number, $\sigma_{0.7} = \dfrac{P_A + P_H - P_V}{(1/2)\rho v_{0.7}{}^2}$
τ	Thrust load coefficient, $\tau = \dfrac{T}{(1/2)\rho A_P v_{0.7}{}^2}$

ABSTRACT

Four commercial propellers were characterized over a range of cavitation numbers and advance coefficients. Three of the propellers were then cupped to different degrees on the trailing edge and characterized over the same range of cavitation numbers and advance coefficients. The results show an increase in K_T, K_Q, and effective pitch corresponding to increasing degrees of cupping. An empirical relationship is derived between the amount of cupping and the resulting increase in effective pitch. It is concluded that cupping is an effective means of correcting an underpitched propeller, at the expense of efficiency and danger of increased cavitation.

ADMINISTRATIVE INFORMATION

This work was performed for Naval Ship Engineering Center, Norfolk Division under Project Order No. N64281-76-PO-6-0005.

INTRODUCTION

Cupped propellers have been manufactured for a number of years and they have become popular for small and medium size pleasure boats. Most manufacturers of small propellers offer one or more of their propeller styles with varying degrees of cupping. Improved performance is claimed for these cupped propellers. Recent full scale trials of the 65' MK III patrol boat appear to support this claim. A significant increase in speed was realized for this craft when a small amount of cupping was applied to her existing propellers. Power measurements prior to cupping, however, indicated that the propellers were not absorbing the full engine power at maximum engine RPM. After cupping these propellers, the maximum available power of the engines was absorbed at the maximum engine RPM, and craft speed increased. It is likely that the increase in power absorbed by the propellers in this case resulted from an effective increase in pitch caused by the cupping.

The cupping of propellers is considered to be an art in the propeller industry. The process (i.e, cupping) increases the effective pitch through deflecting the trailing edge of the propeller-blades (which also increases the trailing edge blade camber). In order to determine the effect of various amounts of cupping on the performance of commercial propellers a limited experimental program was under taken at DTNSRDC. The characteristics of four commercial propellers were determined with and without cupping. The results are reported herein.

The geometry of each propeller along with the range of experimental parameters are shown in Table 1. A photograph of one of these propellers is shown in Figure 1.

TABLE 1

Geometry of the Propellers and Scope of the Experiment

DTNSRDC Propeller Number	Nominal Pitch-Diameter Ratio	Model Propeller Diameter/ins (m)	Expanded Area Ratio	Number of Blades
4685	1.0	12(0.3048)	0.694	3
4686	1.0	12(0.3048)	0.582	3
4687	1.1	12(0.3048)	0.593	3
4688	1.3	12(0.3048)	0.723	3

DTNSRDC Propeller Number	Geometrical Changes	Cavitation Number Range	Advance Coefficient
4685	None	5.8-0.5	0.55-1.05
4685	Cupped	5.8-0.5	0.60-1.05
4686	None	5.8-0.5	0.55-1.05
4686	Cupped	5.8-0.5	0.55-1.05
4687	None	5.8-0.5	0.60-1.15
4687	Cupped	5.8-0.5	0.60-1.15
4688	None	5.8-0.5	0.65-1.40

EXPERIMENTAL PROCEDURE AND RESULTS

Propeller open-water characteristics of the four propellers were obtained in the Center's deep water towing basin. The data were reduced to the usual non-dimensional coefficients of thrust and torque and are presented in Figures 2 and 3. Reynolds number during the open-water characterization varied from 9.0×10^6 to 11.0×10^6.

Cavitation characteristics of the propellers were obtained in the 24-inch variable pressure water tunnel. Tunnel water velocities for each uncupped propeller were established by setting thrust values in the water tunnel equal to the thrust values obtained in open water at the same advance coefficient. Tunnel pressures were adjusted to cover a range of cavitation numbers from 5.8 to 0.5. These cavitation numbers represent a range of ship speed from 12 to 40 knots.

After the uncupped propeller experiments were completed three of the propellers were cupped in the DTNSRDC propeller shop. The blade outline and thickness of these propellers made it difficult to cup them at radii less than 0.5 or greater that 0.9. As a result the cupping is maximum at 0.7 radius and fairs to zero near the hub and at the blade tip. Propellers 4685, 4686 and 4687 were cupped in different amounts designated respectively as heavy, light and medium cupping. Cavitation characteristics of the cupped propellers were obtained over the same range of cavitation numbers and advance coefficients as the uncupped propellers. The thrust and torque data obtained from the cavitation experiments were reduced to the usual nondimensional coefficients, K_T and K_Q. In addition, efficiencies

(η), thrust loading coefficients (K_T/J^2 and τ_c) and torque loading coefficients (K_Q/J^3 and Q_c) were calculated from faired values of thrust and torque coefficients. All the force coefficients are given in Tables 3 through 8.

Curves of the cavitation performance of the propellers are presented in Figures 4 through 14. Sketches of the extent of cavitation on the propeller blades are shown in Figure 15 for the heavily loaded conditions and in Figure 16 for the lightly loaded conditions.

DISCUSSION

When the curves of cavitation performance are treated as typical propeller series data, values of effective pitch may be assigned to the cupped propellers based upon their thrust producing capability. These results are given in Table 2 below:

TABLE 2

Effective Pitch Ratio of Propellers Based on Thrust Performance

DTNSRDC Propeller Number	Geometrical Changes	Effective Pitch Ratio
4685	NONE	1.00
4685	Cupped	1.15
4686	NONE	1.00
4686	Cupped	1.05
4687	NONE	1.10
4687	Cupped	1.18
4688	NONE	1.30

By correlating the change in effective pitch of these propellers and the amount of cupping done to them, an empirical relationship has been established to calculate the degree of cupping needed to accomplish a predetermined change in effective pitch.

If one associates cupping with the added deflection of the blade trailing edge after cupping (the deflection being measured perpendicular to the nose-tail-line of the blade, at the 0.7 radius), cupping may be defined as:

(See Figure 17)

$$x = (1/2) C_{0.7} \tan \theta_A$$

where

x = amount of cupping at 0.7 R

$C_{0.7}$ = blade chord length at 0.7 R

θ_A = the approximate change in pitch angle between propeller pitch and desired propeller pitch.

If p_n and θ_n are the new pitch and pitch angle desired, where $\theta_n = \tan^{-1} \left(\frac{P_n}{2\pi r_{0.7}}\right)$

$$\theta_A = \theta_n - \theta_o = \tan^{-1} \left(\frac{P_n}{2\pi r_{0.7}}\right) - \tan^{-1} \left(\frac{P_o}{2\pi r_{0.7}}\right)$$

where θ_o and P_o are the original pitch and pitch angle.

It was found that the proper cupping can be achieved by using a ball or curved anvil. The radius of the ball may be determined by using the following equation (See Figure 18 for definition):

$$r = \frac{x^2 + y^2}{2x}$$

where

r = radius of desired ball

x = amount of cupping at 0.7R

y = 10% of blade chord length at 0.7R

A numerical example for these computations is shown in Appendix A. In cupping the propellers the center of the ball should be positioned at 90% of the chord length from the leading edge of the blade, starting at the hub and progressing toward the tip to 0.9R. From 0.9R to 0.95R the center of the ball moves linearly from 90% of

the chord length to 100% of the chord (i.e., to the trailing edge).

Propeller cupping is a practical method for increasing the effective pitch of an existing propeller. However, there are two potential problem areas. One problem is that the cupping produces a blade trailing edge which is susceptible to trailing edge cavitation. This effect is illustrated by the sketches of cavitation present, under typical operating conditions, on these propellers (See Figures 15, 16, and 17). Also cupped propellers, in general, seem to have a somewhat lower efficiency than propellers designed specifically for the desired pitch. Thus cupping is recommended only when the existing propeller is underpitched and the required higher pitch propeller is not readily available.

CONCLUSION AND RECOMMENDATIONS

An approximate definition of cupping was derived from data obtained using four commercial propellers. It appears that the cupping of an in-service propeller is an effective measure to correct the initial mis-match between the propeller and the powering system. A properly cupped propeller will absorb the available power at the expense of lower efficiency and with the possibility of an increased amount of cavitation.

Based on this limited sample (only four propellers were evaluated), it is recommended that cupping only be used as a corrective measure.

The empirical relationship between cupping and effective pitch, in a strict sense, is valid only for the type of cupping described in this report. If a different method is used to achieve cupping, the conclusions drawn from these experiments may not be valid. A much larger sample of commercially cupped propellers would be required if one desires to arrive at a "general rule of thumb".

APPENDIX A

The procedure to follow in order to determine the amount of cupping needed to raise the effective pitch of an existing propeller to some new value is as follows:

1. Estimate the desired pitch ratio and calculate the new pitch. For this pitch, the new pitch angle, θ_n is

$$\theta_n = \tan^{-1} \left(\frac{P_n}{2\pi r_{0.7}}\right)$$

2. Calculate the required additional pitch angle θ_A:

$\theta_A = \theta_n - \theta_o$, where θ_o is the original pitch angle.

3. The trailing edge of the propeller should be cupped, at the 0.7 radius, an amount

$$x = \left(\frac{C_{0.7}}{2}\right) \tan \theta_A \quad [\text{in}]$$

For example consider a propeller of:

$$D = 2.5 \text{ ft } (.762 \text{ m})$$

$$P/D = 1.0$$

$$C_{0.7} = 1.458 \text{ ft } (.444\text{m})$$

How much should this propeller be cupped to achieve a desired P/D = 1.1?

The original pitch is $P = (D)(P/D) = (2.5 \text{ ft})(1.0) = 2.5$ ft

The original pitch angle is $\theta_o = \tan^{-1}\left(\frac{P}{2\pi r_{0.7}}\right) = \tan^{-1}\left[\frac{2.5}{(2)(\pi)(.87)}\right] = 24.453°$

The new pitch is $P = (2.5)(1.1) = 2.75$ ft

The new pitch angle is $\theta_n = \tan^{-1}\left(\frac{P}{2\pi r_{o.7}}\right) = \tan^{-1}\left[\frac{2.75}{(2)(\pi)(.87)}\right] = 26.706°$

Therefore:

$$\theta_A = \theta_n - \theta_o = 26.706 - 24.453 = 2.253°$$

Then the amount of cupping needed, x, is

$x = \left(\frac{C_{0.7}}{2}\right) \tan \theta_A = \left(\frac{1.458}{2}\right) \tan 2.253° = .029 \text{ ft} = .344$ inches (.009 m)

The ball radius needed to effect this amount of cupping is:

$$r = \frac{x^2 + y^2}{2x}$$

where $x = .344$ inches
$y = 10\%$ of blade chord at 0.7 R=1.749 in (.0444 m)

$$r = \frac{(.344)^2+(1.749)^2}{2(.344)}$$

$$= 4.62 \text{ in } (.1174 \text{ m})$$

Table 3

Cavitation Performance Characteristics of Propeller 4685 Cupped

PROPELLER NUMBER =4685 PITCH RATIO = 1.000 SIGMA = 5.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.2874	.5499	.4991	.7984	.2546	.0464	.4015	.1901
.6500	.2709	.5363	.5226	.6413	.1953	.0447	.4657	.1770
.7000	.2512	.5159	.5426	.5127	.1504	.0424	.5332	.1621
.7500	.2301	.4914	.5591	.4091	.1165	.0399	.6039	.1465
.8000	.2088	.4649	.5718	.3262	.0908	.0372	.6774	.1310
.8500	.1875	.4375	.5800	.2596	.0712	.0345	.7533	.1159
.9000	.1662	.4096	.5811	.2051	.0562	.0318	.8315	.1011
.9500	.1436	.3806	.5706	.1592	.0444	.0291	.9115	.0860
1.0000	.1183	.3494	.5390	.1183	.0349	.0262	.9932	.0697
1.0500	.0878	.3136	.4680	.0797	.0271	.0231	1.0761	.0508

PROPELLER NUMBER =4685 PITCH RATIO = 1.000 SIGMA = 3.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.2536	.4822	.5023	.7045	.2232	.0407	.2077	.1677
.6500	.2419	.4812	.5200	.5725	.1752	.0401	.2409	.1581
.7000	.2323	.4781	.5413	.4740	.1394	.0393	.2758	.1499
.7500	.2221	.4703	.5637	.3948	.1115	.0382	.3124	.1414
.8000	.2094	.4563	.5844	.3272	.0891	.0365	.3504	.1314
.8500	.1932	.4355	.6002	.2674	.0709	.0343	.3897	.1195
.9000	.1732	.4082	.6077	.2138	.0560	.0317	.4301	.1054
.9500	.1499	.3756	.6033	.1661	.0438	.0287	.4715	.0897
1.0000	.1247	.3398	.5839	.1247	.0340	.0259	.5137	.0734
1.0500	.0998	.3040	.5485	.0905	.0263	.0224	.5566	.0577

PROPELLER NUMBER =4685 PITCH RATIO = 1.000 SIGMA = 1.5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6500	.2062	.3855	.5534	.4881	.1404	.0321	.1204	.1348
.7000	.1972	.3879	.5665	.4025	.1131	.0319	.1379	.1273
.7500	.1884	.3863	.5821	.3349	.0916	.0314	.1562	.1199
.8000	.1789	.3828	.5952	.2796	.0748	.0308	.1752	.1123
.8500	.1680	.3774	.6024	.2326	.0614	.0297	.1948	.1039
.9000	.1544	.3674	.6020	.1906	.0504	.0285	.2150	.0940
.9500	.1365	.3478	.5932	.1512	.0406	.0266	.2357	.0817
1.0000	.1124	.3115	.5742	.1124	.0311	.0234	.2568	.0662
1.0500	.0800	.2484	.5378	.0725	.0215	.0183	.2783	.0463

PROPELLER NUMBER =4685 PITCH RATIO = 1.000 SIGMA = .75

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.0899	.2018	.4267	.2495	.0931	.0169	.0519	.0594
.6500	.1041	.2224	.4842	.2464	.0810	.0188	.0602	.0680
.7000	.1153	.2471	.5199	.2353	.0720	.0203	.0689	.0744
.7500	.1213	.2658	.5445	.2156	.0630	.0216	.0781	.0772
.8000	.1207	.2730	.5629	.1886	.0533	.0219	.0876	.0757
.8500	.1130	.2661	.5745	.1564	.0433	.0219	.0974	.0699
.9000	.0983	.2458	.5727	.1213	.0337	.0191	.1075	.0598
.9500	.0774	.2163	.5411	.0858	.0252	.0165	.1179	.0464
1.0000	.0519	.1847	.4474	.0519	.0185	.0139	.1284	.0308
1.0500	.0242	.1617	.2499	.0219	.0140	.0119	.1391	.0140

PROPELLER NUMBER =4685 PITCH RATIO = 1.000 SIGMA = .5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.0767	.1813	.4038	.2129	.0839	.0153	.0346	.0507
.6500	.0756	.1765	.4433	.1790	.0643	.0147	.0401	.0494
.7000	.0819	.1873	.4870	.1671	.0546	.0154	.0460	.0528
.7500	.0886	.2016	.5250	.1576	.0478	.0164	.0521	.0564
.8000	.0910	.2102	.5511	.1422	.0411	.0168	.0584	.0571
.8500	.0857	.2070	.5599	.1186	.0337	.0163	.0649	.0530
.9000	.0712	.1886	.5412	.0883	.0259	.0146	.0717	.0434
.9500	.0479	.1543	.4698	.0531	.0180	.0118	.0786	.0287
1.0000	.0178	.1066	.2657	.0178	.0107	.0080	.0856	.0105
1.0500	-.0155	.0506	-.5099	-.0140	.0044	.0037	.0928	-.0089

Table 4

Cavitation Performance Characteristics of Propeller 4686

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = 5.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.5500	.2461	.4114	.5236	.8135	.2473	.0357	.3412	.1675
.6000	.2229	.3829	.5559	.6191	.1773	.0329	.4015	.1500
.6500	.1999	.3524	.5868	.4731	.1203	.0299	.4657	.1329
.7000	.1771	.3210	.6146	.3614	.0936	.0269	.5332	.1163
.7500	.1543	.2894	.6367	.2744	.0686	.0239	.6039	.1000
.8000	.1317	.2580	.6501	.2058	.0504	.0210	.6774	.0841
.8500	.1091	.2268	.6511	.1511	.0369	.0182	.7533	.0687
.9000	.0867	.1955	.6349	.1070	.0268	.0154	.8315	.0537
.9500	.0643	.1634	.5945	.0712	.0191	.0127	.9225	.0392
1.0000	.0420	.1298	.5159	.0420	.0130	.0099	.9932	.0252
1.0500	.0200	.0927	.3597	.0181	.0080	.0070	1.0751	.0117

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = 3.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.5500	.2242	.3919	.5009	.7412	.2355	.0340	.1765	.1526
.6000	.2125	.3783	.5364	.5902	.1751	.0325	.2077	.1430
.6500	.1942	.3522	.5705	.4597	.1282	.0299	.2409	.1292
.7000	.1728	.3197	.6022	.3527	.0932	.0268	.2758	.1135
.7500	.1507	.2856	.6297	.2679	.0677	.0236	.3124	.0976
.8000	.1293	.2530	.6506	.2020	.0494	.0206	.3504	.0826
.8500	.1090	.2233	.6607	.1509	.0364	.0179	.3897	.0686
.9000	.0895	.1964	.6526	.1105	.0269	.0155	.4301	.0554
.9500	.0691	.1707	.6121	.0766	.0199	.0133	.4715	.0421
1.0000	.0455	.1429	.5066	.0455	.0143	.0109	.5137	.0272
1.0500	.0152	.1081	.2365	.0138	.0093	.0081	.5566	.0089

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = 1.5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.5500	.1163	.2326	.4375	.3843	.1398	.0202	.0882	.0791
.6000	.1430	.2749	.4994	.3993	.1273	.0236	.1038	.0967
.6500	.1572	.2895	.5617	.3720	.1054	.0245	.1204	.1045
.7000	.1589	.2856	.6201	.3244	.0833	.0239	.1379	.1044
.7500	.1513	.2704	.6681	.2691	.0641	.0223	.1562	.0980
.8000	.1365	.2492	.6976	.2133	.0487	.0203	.1752	.0872
.8500	.1165	.2250	.7005	.1613	.0366	.0189	.1948	.0733
.9000	.0931	.1990	.6706	.1150	.0273	.0157	.2150	.0577
.9500	.0681	.1701	.6056	.0755	.0198	.0132	.2357	.0415
1.0000	.0430	.1353	.5059	.0430	.0135	.0103	.2568	.0253
1.0500	.0192	.0895	.3583	.0174	.0077	.0067	.2783	.0113

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = .75

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.0501	.1200	.3955	.1390	.0559	.0104	.0519	.0337
.6500	.0630	.1398	.4660	.1491	.0509	.0119	.0602	.0419
.7000	.0744	.1595	.5201	.1519	.0465	.0133	.0689	.0489
.7500	.0821	.1751	.5600	.1460	.0415	.0145	.0781	.0532
.8000	.0844	.1829	.5876	.1319	.0357	.0149	.0876	.0539
.8500	.0801	.1799	.6025	.1109	.0293	.0144	.0974	.0504
.9000	.0689	.1643	.6007	.0851	.0225	.0130	.1075	.0427
.9500	.0509	.1349	.5703	.0564	.0157	.0109	.1179	.0310
1.0000	.0269	.0916	.4665	.0269	.0092	.0070	.1284	.0161
1.0500	-.0019	.0353	-.0830	-.0016	.0030	.0026	.1391	-.0018

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = .5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6500	.0274	.0812	.3409	.0648	.0296	.0069	.0401	.0182
.7000	.0339	.0938	.4064	.0692	.0271	.0078	.0460	.0223
.7500	.0414	.1061	.4654	.0735	.0251	.0088	.0521	.0260
.8000	.0460	.1147	.5106	.0719	.0224	.0093	.0584	.0294
.8500	.0452	.1145	.5336	.0625	.0186	.0092	.0649	.0284
.9000	.0372	.1026	.5200	.0460	.0141	.0081	.0717	.0231
.9500	.0218	.0778	.4236	.0241	.0091	.0060	.0786	.0133
1.0000	-.0006	.0403	-.0240	-.0006	.0040	.0031	.0856	-.0004
1.0500	-.0282	-.0001	5.8424	-.0256	-.0007	-.0006	.0928	-.0166

Table 5

Cavitation Performance Characteristics of Propeller 4686 Cupped

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = 5.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.5500	.2650	.4629	.5011	.8759	.2782	.0402	.3412	.1803
.6000	.2432	.4363	.5323	.6755	.2020	.0374	.4015	.1636
.6500	.2205	.4050	.5631	.5219	.1475	.0343	.4657	.1466
.7000	.1982	.3720	.5937	.4046	.1085	.0311	.5332	.1302
.7500	.1772	.3390	.6239	.3150	.0804	.0280	.6039	.1140
.8000	.1576	.3072	.6531	.2462	.0600	.0250	.6774	.1006
.8500	.1390	.2767	.6795	.1924	.0451	.0222	.7533	.0874
.9000	.1205	.2469	.6991	.1488	.0339	.0195	.8315	.0746
.9500	.1006	.2162	.7030	.1115	.0252	.0168	.9115	.0613
1.0000	.0773	.1822	.6754	.0773	.0182	.0139	.9932	.0463
1.0500	.0479	.1415	.5654	.0434	.0122	.0108	1.0761	.0282

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = 3.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.5500	.2301	.4204	.4866	.7872	.2575	.0372	.1765	.1621
.6000	.2296	.4192	.5229	.6376	.1941	.0360	.2077	.1545
.6500	.2145	.3989	.5564	.5078	.1452	.0338	.2409	.1427
.7000	.1958	.3717	.5870	.3996	.1084	.0311	.2758	.1286
.7500	.1754	.3408	.6144	.3119	.0808	.0281	.3124	.1136
.8000	.1548	.3089	.6381	.2418	.0603	.0251	.3504	.0988
.8500	.1365	.2771	.6567	.1882	.0451	.0222	.3897	.0846
.9000	.1146	.2461	.6671	.1415	.0338	.0194	.4301	.0718
.9500	.0944	.2153	.6627	.1046	.0251	.0167	.4715	.0575
1.0000	.0725	.1835	.6286	.0725	.0183	.0140	.5137	.0434
1.0500	.0468	.1401	.5277	.0424	.0120	.0111	.5566	.0275

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = 1.5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.5500	.1317	.2627	.4390	.4355	.1579	.0228	.0882	.0896
.6000	.1574	.2978	.5047	.4372	.1379	.0256	.1038	.1059
.6500	.1694	.3178	.5512	.4008	.1157	.0269	.1204	.1126
.7000	.1709	.3243	.5869	.3487	.0946	.0272	.1379	.1122
.7500	.1646	.3198	.6161	.2927	.0756	.0263	.1562	.1066
.8000	.1528	.3034	.6414	.2388	.0593	.0247	.1752	.0976
.8500	.1372	.2796	.6637	.1898	.0455	.0224	.1948	.0863
.9000	.1188	.2494	.6821	.1466	.0342	.0197	.2150	.0736
.9500	.0983	.2150	.6912	.1089	.0251	.0167	.2357	.0599
1.0000	.0759	.1786	.6762	.0759	.0179	.0136	.2568	.0455
1.0500	.0511	.1424	.5997	.0463	.0123	.0107	.2783	.0301

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = .75

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.0673	.1511	.4249	.1868	.0700	.0130	.0519	.0453
.6500	.0842	.1792	.4860	.1993	.0653	.0152	.0602	.0560
.7000	.0965	.2008	.5355	.1970	.0585	.0168	.0689	.0634
.7500	.1031	.2143	.5744	.1833	.0508	.0177	.0781	.0668
.8000	.1034	.2187	.6019	.1616	.0427	.0179	.0876	.0660
.8500	.0973	.2136	.6162	.1347	.0348	.0171	.0974	.0612
.9000	.0852	.1990	.6134	.1052	.0273	.0157	.1075	.0528
.9500	.0680	.1754	.5860	.0753	.0205	.0136	.1179	.0414
1.0000	.0470	.1439	.5197	.0470	.0144	.0118	.1284	.0282
1.0500	.0240	.1060	.3791	.0218	.0092	.0088	.1391	.0142

PROPELLER NUMBER =4686 PITCH RATIO = 1.000 SIGMA = .5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6500	.0391	.1034	.3911	.0925	.0377	.0088	.0401	.0260
.7000	.0378	.1036	.4063	.0771	.0302	.0087	.0460	.0248
.7500	.0477	.1214	.4693	.0848	.0288	.0100	.0521	.0309
.8000	.0570	.1387	.5233	.0891	.0271	.0113	.0584	.0364
.8500	.0580	.1436	.5468	.0803	.0234	.0115	.0649	.0365
.9000	.0476	.1305	.5225	.0588	.0179	.0103	.0717	.0295
.9500	.0269	.1004	.4058	.0298	.0117	.0078	.0786	.0164
1.0000	.0015	.0601	.0402	.0015	.0060	.0046	.0856	.0009
1.0500	-.0187	.0233	******	-.0170	.0020	.0017	.0928	-.0118

Table 6

Cavitation Performance Characteristics of Propeller 4687

PROPELLER NUMBER =4687   PITCH RATIO = 1.100   SIGMA = 5.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.2810	.5385	.4982	.7805	.2493	.0468	.4015	.1913
.6500	.2561	.5015	.5283	.6061	.1826	.0430	.4657	.1723
.7000	.2310	.4613	.5579	.4714	.1345	.0391	.5337	.1534
.7500	.2060	.4200	.5854	.3661	.0996	.0351	.6039	.1350
.8000	.1811	.3791	.6083	.2830	.0740	.0312	.6774	.1170
.8500	.1566	.3396	.6239	.2167	.0553	.0276	.7533	.0997
.9000	.1325	.3017	.6291	.1636	.0414	.0241	.8315	.0830
.9500	.1089	.2654	.6205	.1207	.0310	.0209	.9115	.0671
1.0000	.0858	.2290	.5963	.0858	.0230	.0178	.9932	.0520
1.0500	.0632	.1935	.5454	.0573	.0167	.0147	1.0761	.0376
1.1000	.0409	.1540	.4631	.0338	.0116	.0115	1.1600	.0240
1.1500	.0190	.1110	.3137	.0144	.0073	.0081	1.2447	.0109

PROPELLER NUMBER =4687   PITCH RATIO = 1.100   SIGMA = 3.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.2699	.5211	.4947	.7498	.2412	.0452	.2077	.1938
.6500	.2586	.5019	.5330	.6121	.1828	.0431	.2409	.1760
.7000	.2408	.4706	.5701	.4915	.1372	.0399	.2758	.1600
.7500	.2187	.4319	.6044	.3888	.1024	.0361	.3124	.1433
.8000	.1948	.3893	.6344	.3031	.0760	.0321	.3504	.1253
.8500	.1681	.3459	.6577	.2327	.0563	.0281	.3897	.1079
.9000	.1427	.3033	.6715	.1759	.0416	.0242	.4301	.0891
.9500	.1167	.2623	.6727	.1293	.0306	.0206	.4715	.0720
1.0000	.0920	.2230	.6569	.0920	.0223	.0177	.5137	.0558
1.0500	.0680	.1841	.6176	.0617	.0159	.0149	.5566	.0405
1.1000	.0442	.1430	.5383	.0365	.0108	.0107	.6000	.0259
1.1500	.0197	.0980	.3663	.0149	.0065	.0077	.6438	.0113

PROPELLER NUMBER =4687   PITCH RATIO = 1.100   SIGMA = 1.5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.1550	.3268	.4529	.4305	.1513	.0284	.1038	.1055
.6500	.1866	.3850	.5016	.4418	.1402	.0339	.1204	.1256
.7000	.2008	.4085	.5476	.4097	.1191	.0346	.1379	.1334
.7500	.2011	.4062	.5909	.3575	.0963	.0339	.1562	.1318
.8000	.1910	.3858	.6302	.2984	.0754	.0318	.1752	.1234
.8500	.1734	.3536	.6634	.2400	.0576	.0287	.1948	.1104
.9000	.1510	.3146	.6875	.1864	.0431	.0251	.2150	.0946
.9500	.1259	.2724	.6990	.1395	.0318	.0214	.2357	.0776
1.0000	.1001	.2295	.6942	.1001	.0230	.0177	.2569	.0607
1.0500	.0750	.1870	.6699	.0680	.0162	.0142	.2783	.0447
1.1000	.0516	.1447	.6241	.0426	.0109	.0108	.3000	.0302
1.1500	.0306	.1010	.5551	.0232	.0066	.0074	.3719	.0176

PROPELLER NUMBER =4687   PITCH RATIO = 1.100   SIGMA = .75

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.0597	.1496	.3740	.1631	.0692	.0170	.0519	.0488
.6500	.0673	.1670	.4160	.1593	.0608	.0143	.0602	.0453
.7000	.0837	.1980	.4710	.1708	.0577	.0168	.0689	.0596
.7500	.1013	.2305	.5245	.1801	.0546	.0193	.0781	.0664
.8000	.1151	.2558	.5732	.1798	.0499	.0211	.0876	.0744
.8500	.1217	.2676	.6157	.1685	.0435	.0217	.0974	.0775
.9000	.1194	.2629	.6509	.1475	.0361	.0210	.1075	.0749
.9500	.1082	.2420	.6758	.1199	.0282	.0190	.1179	.0667
1.0000	.0894	.2078	.6865	.0894	.0208	.0161	.1284	.0542
1.0500	.0662	.1663	.6654	.0601	.0144	.0126	.1391	.0395
1.1000	.0435	.1265	.6017	.0359	.0095	.0094	.1500	.0254
1.1500	.0275	.1004	.5019	.0208	.0066	.0074	.1610	.0158

PROPELLER NUMBER =4687   PITCH RATIO = 1.100   SIGMA = .6

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6500	.0455	.1299	.3626	.1077	.0473	.0111	.0401	.0308
.7000	.0422	.1177	.3997	.0862	.0343	.0100	.0460	.0281
.7500	.0488	.1294	.4505	.0868	.0307	.0109	.0521	.0320
.8000	.0593	.1513	.4988	.0926	.0295	.0125	.0584	.0383
.8500	.0687	.1725	.5389	.0951	.0281	.0140	.0649	.0437
.9000	.0737	.1851	.5704	.0910	.0254	.0148	.0717	.0462
.9500	.0721	.1841	.5922	.0799	.0215	.0145	.0786	.0445
1.0000	.0630	.1671	.5999	.0630	.0167	.0129	.0856	.0382
1.0500	.0468	.1349	.5801	.0425	.0117	.0102	.0928	.0279
1.1000	.0253	.0908	.4880	.0209	.0068	.0068	.1000	.0148
1.1500	.0015	.0412	.0664	.0011	.0027	.0030	.1073	.0009

Table 7

Cavitation Performance Characteristics of Propeller 4687 Cupped

PROPELLER NUMBER =4687 PITCH RATIO = 1.100 SIGMA = 5.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.3148	.6212	.4839	.8744	.2876	.0539	.4015	.2143
.6500	.2956	.5839	.5237	.6996	.2126	.0501	.4657	.1989
.7000	.2735	.5464	.5577	.5582	.1593	.0463	.5332	.1817
.7500	.2497	.5088	.5859	.4440	.1206	.0425	.6039	.1637
.8000	.2251	.4709	.6086	.3517	.0920	.0388	.6774	.1454
.8500	.2002	.4327	.6260	.2771	.0705	.0351	.7533	.1274
.9000	.1756	.3942	.6301	.2168	.0541	.0315	.8315	.1100
.9500	.1514	.3553	.6443	.1678	.0414	.0279	.9115	.0933
1.0000	.1276	.3161	.6426	.1276	.0316	.0244	.9932	.0774
1.0500	.1040	.2765	.6207	.0943	.0239	.0210	1.0761	.0620
1.1000	.0801	.2366	.5929	.0662	.0178	.0177	1.1600	.0469
1.1500	.0553	.1965	.5147	.0418	.0129	.0144	1.2447	.0317

PROPELLER NUMBER =4687 PITCH RATIO = 1.100 SIGMA = 3.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6500	.2766	.5690	.5030	.6548	.2072	.0488	.2409	.1861
.7000	.2649	.5489	.5377	.5407	.1600	.0465	.2758	.1760
.7500	.2469	.5175	.5694	.4389	.1227	.0437	.3124	.1618
.8000	.2249	.4796	.5970	.3514	.0937	.0395	.3504	.1453
.8500	.2008	.4389	.6191	.2780	.0715	.0356	.3897	.1278
.9000	.1761	.3978	.6341	.2174	.0546	.0318	.4301	.1104
.9500	.1516	.3578	.6407	.1680	.0417	.0281	.4715	.0935
1.0000	.1278	.3193	.6373	.1278	.0319	.0247	.5137	.0775
1.0500	.1047	.2812	.6223	.0950	.0243	.0214	.5566	.0624
1.1000	.0817	.2416	.5920	.0675	.0182	.0180	.6000	.0478
1.1500	.0578	.1974	.5360	.0437	.0130	.0145	.6438	.0332

PROPELLER NUMBER =4687 PITCH RATIO = 1.100 SIGMA = 1.5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.1747	.3757	.4439	.4851	.1739	.0326	.1038	.1189
.6500	.2025	.4381	.4780	.4792	.1595	.0376	.1204	.1362
.7000	.2148	.4673	.5121	.4384	.1362	.0396	.1379	.1427
.7500	.2152	.4719	.5444	.3826	.1119	.0394	.1562	.1411
.8000	.2068	.4593	.5732	.3231	.0897	.0378	.1752	.1336
.8500	.1920	.4353	.5967	.2658	.0709	.0353	.1948	.1222
.9000	.1732	.4046	.6130	.2138	.0555	.0323	.2150	.1085
.9500	.1520	.3704	.6204	.1684	.0432	.0291	.2357	.0937
1.0000	.1297	.3344	.6172	.1297	.0334	.0258	.2568	.0786
1.0500	.1071	.2970	.6027	.0972	.0257	.0226	.2783	.0638
1.1000	.0847	.2575	.5761	.0700	.0193	.0192	.3000	.0496
1.1500	.0624	.2134	.5355	.0472	.0140	.0156	.3219	.0359

PROPELLER NUMBER =4687 PITCH RATIO = 1.100 SIGMA = .75

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6000	.0754	.1832	.3928	.2094	.0848	.0159	.0519	.0513
.6500	.0856	.2070	.4275	.2025	.0754	.0178	.0602	.0576
.7000	.1026	.2425	.4715	.2095	.0707	.0205	.0689	.0682
.7500	.1204	.2787	.5155	.2140	.0661	.0233	.0781	.0789
.8000	.1341	.3074	.5552	.2095	.0600	.0253	.0876	.0866
.8500	.1407	.3232	.5889	.1947	.0526	.0262	.0974	.0895
.9000	.1388	.3234	.6147	.1713	.0444	.0258	.1075	.0870
.9500	.1285	.3081	.6307	.1424	.0359	.0242	.1179	.0792
1.0000	.1116	.2800	.6342	.1116	.0280	.0216	.1284	.0677
1.0500	.0914	.2448	.6237	.0829	.0211	.0186	.1391	.0544
1.1000	.0728	.2107	.6045	.0601	.0158	.0157	.1500	.0426
1.1500	.0623	.1889	.6039	.0471	.0124	.0130	.1610	.0350

PROPELLER NUMBER =4687 PITCH RATIO = 1.100 SIGMA = .5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6500	.0606	.1659	.3778	.1434	.0604	.0142	.0401	.0408
.7000	.0600	.1599	.4182	.1225	.0466	.0135	.0460	.0399
.7500	.0675	.1731	.4653	.1200	.0410	.0145	.0521	.0442
.8000	.0785	.1957	.5106	.1227	.0382	.0161	.0584	.0507
.8500	.0893	.2197	.5501	.1237	.0358	.0178	.0649	.0569
.9000	.0969	.2384	.5825	.1197	.0327	.0190	.0717	.0607
.9500	.0988	.2465	.6062	.1095	.0288	.0194	.0786	.0609
1.0000	.0933	.2406	.6175	.0933	.0241	.0186	.0856	.0566
1.0500	.0794	.2184	.6073	.0720	.0189	.0168	.0928	.0473
1.1000	.0565	.1793	.5516	.0467	.0135	.0134	.1000	.0331
1.1500	.0250	.1243	.3686	.0189	.0082	.0091	.1073	.0144

Table 8

Cavitation Performance Characteristics of Propeller 4688

PROPELLER NUMBER =4688 PITCH RATIO = 1.300 SIGMA = 5.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.6500	.3760	.8159	.4767	.8899	.2971	.0711	.4657	.2569
.7000	.3500	.7653	.5095	.7143	.2231	.0658	.5332	.2361
.7500	.3240	.7167	.5396	.5759	.1699	.0608	.6039	.2156
.8000	.2979	.6694	.5667	.4655	.1307	.0568	.6774	.1955
.8500	.2720	.6230	.5986	.3765	.1014	.0513	.7533	.1758
.9000	.2463	.5772	.6112	.3040	.0792	.0468	.8315	.1567
.9500	.2209	.5310	.6280	.2447	.0620	.0425	.9115	.1383
1.0000	.1950	.4860	.6403	.1950	.0487	.0382	.9932	.1206
1.0500	.1712	.4422	.6469	.1553	.0382	.0341	1.0761	.1036
1.1000	.1471	.3985	.6462	.1216	.0299	.0302	1.1600	.0874
1.1500	.1235	.3558	.6351	.0934	.0234	.0265	1.2447	.0720
1.2000	.1004	.3149	.6091	.0697	.0182	.0230	1.3299	.0575
1.2500	.0780	.2764	.5612	.0499	.0142	.0198	1.4155	.0438
1.3000	.0561	.2411	.4814	.0332	.0110	.0169	1.5011	.0309
1.3500	.0348	.2099	.3561	.0191	.0085	.0144	1.5866	.0188
1.4000	.0141	.1841	.1784	.0072	.0067	.0124	1.6718	.0074

PROPELLER NUMBER =4688 PITCH RATIO = 1.300 SIGMA = 3.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.7000	.3294	.7343	.4937	.6641	.2141	.0632	.2750	.2195
.7500	.3154	.7126	.5203	.5607	.1689	.0605	.3124	.2099
.8000	.2981	.6784	.5596	.4659	.1325	.0568	.3504	.1956
.8500	.2758	.6355	.5870	.3817	.1035	.0524	.3897	.1783
.9000	.2499	.5874	.6095	.3086	.0806	.0477	.4301	.1591
.9500	.2222	.5367	.6260	.2462	.0626	.0429	.4715	.1391
1.0000	.1938	.4857	.6350	.1938	.0486	.0381	.5137	.1193
1.0500	.1656	.4350	.6358	.1502	.0376	.0336	.5566	.1002
1.1000	.1384	.3881	.6244	.1144	.0292	.0294	.6000	.0823
1.1500	.1126	.3420	.6013	.0852	.0225	.0255	.6438	.0657
1.2000	.0884	.2990	.5631	.0614	.0174	.0219	.6879	.0506
1.2500	.0657	.2583	.5059	.0420	.0132	.0185	.7321	.0369
1.3000	.0441	.2167	.4208	.0261	.0099	.0152	.7764	.0243
1.3500	.0230	.1731	.2856	.0126	.0070	.0119	.8206	.0126
1.4000	.0016	.1240	.0281	.0008	.0045	.0084	.8647	.0008

PROPELLER NUMBER =4688 PITCH RATIO = 1.300 SIGMA = 1.5

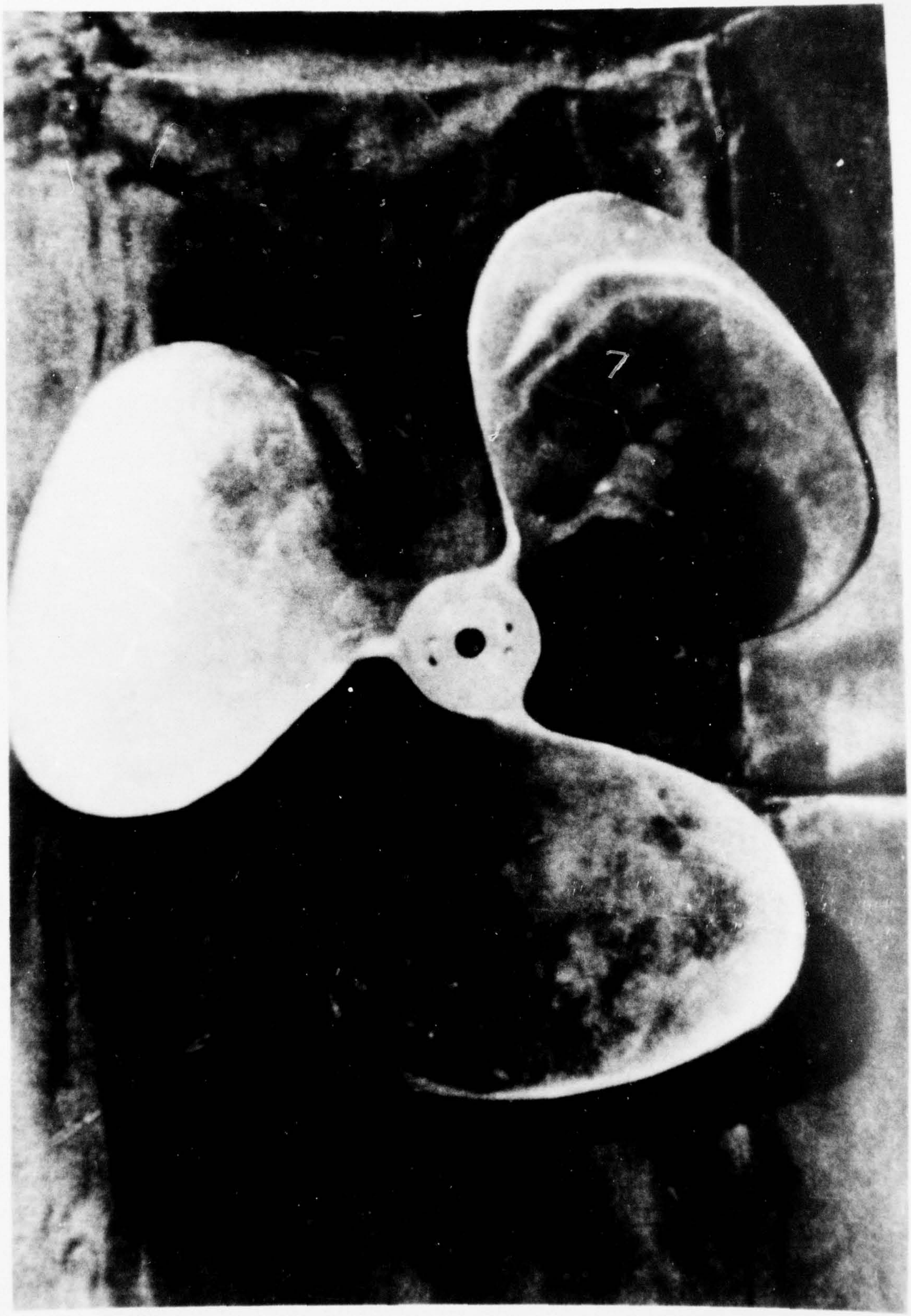
J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.8000	.2381	.5774	.5250	.3720	.1128	.0483	.1752	.1562
.8500	.2474	.5903	.5669	.3424	.0961	.0487	.1948	.1599
.9000	.2399	.5728	.5990	.2961	.0786	.0465	.2150	.1527
.9500	.2211	.5356	.6241	.2450	.0625	.0428	.2357	.1384
1.0000	.1957	.4875	.6390	.1957	.0487	.0383	.2568	.1205
1.0500	.1674	.4352	.6427	.1518	.0376	.0338	.2783	.1013
1.1000	.1389	.3838	.6335	.1148	.0288	.0291	.3000	.0826
1.1500	.1121	.3362	.6103	.0848	.0221	.0250	.3219	.0654
1.2000	.0879	.2935	.5722	.0611	.0170	.0214	.3439	.0503
1.2500	.0664	.2546	.5184	.0425	.0130	.0182	.3661	.0373
1.3000	.0465	.2170	.4429	.0275	.0099	.0152	.3882	.0256
1.3500	.0264	.1757	.3225	.0145	.0071	.0121	.4103	.0142
1.4000	.0034	.1242	.0602	.0017	.0045	.0084	.4324	.0018

PROPELLER NUMBER =4688 PITCH RATIO = 1.300 SIGMA = .75

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.7500	.0992	.2766	.4281	.1764	.0656	.0235	.0781	.0660
.8000	.1091	.3041	.4569	.1705	.0594	.0254	.0876	.0716
.8500	.1220	.3350	.4920	.1689	.0545	.0278	.0974	.0789
.9000	.1342	.3624	.5304	.1657	.0497	.0294	.1075	.0854
.9500	.1420	.3812	.5605	.1583	.0445	.0304	.1179	.0894
1.0000	.1459	.3877	.5987	.1459	.0388	.0304	.1284	.0898
1.0500	.1421	.3801	.6249	.1289	.0328	.0293	.1391	.0868
1.1000	.1313	.3580	.6422	.1085	.0269	.0271	.1500	.0781
1.1500	.1140	.3220	.6462	.0862	.0212	.0240	.1610	.0665
1.2000	.0914	.2773	.6294	.0634	.0160	.0202	.1720	.0523
1.2500	.0690	.2261	.5707	.0421	.0116	.0162	.1830	.0369
1.3000	.0402	.1794	.4741	.0238	.0080	.0123	.1941	.0221
1.3500	.0185	.1330	.2993	.0102	.0054	.0092	.2052	.0100
1.4000	.0055	.1084	.1132	.0028	.0039	.0073	.2162	.0029

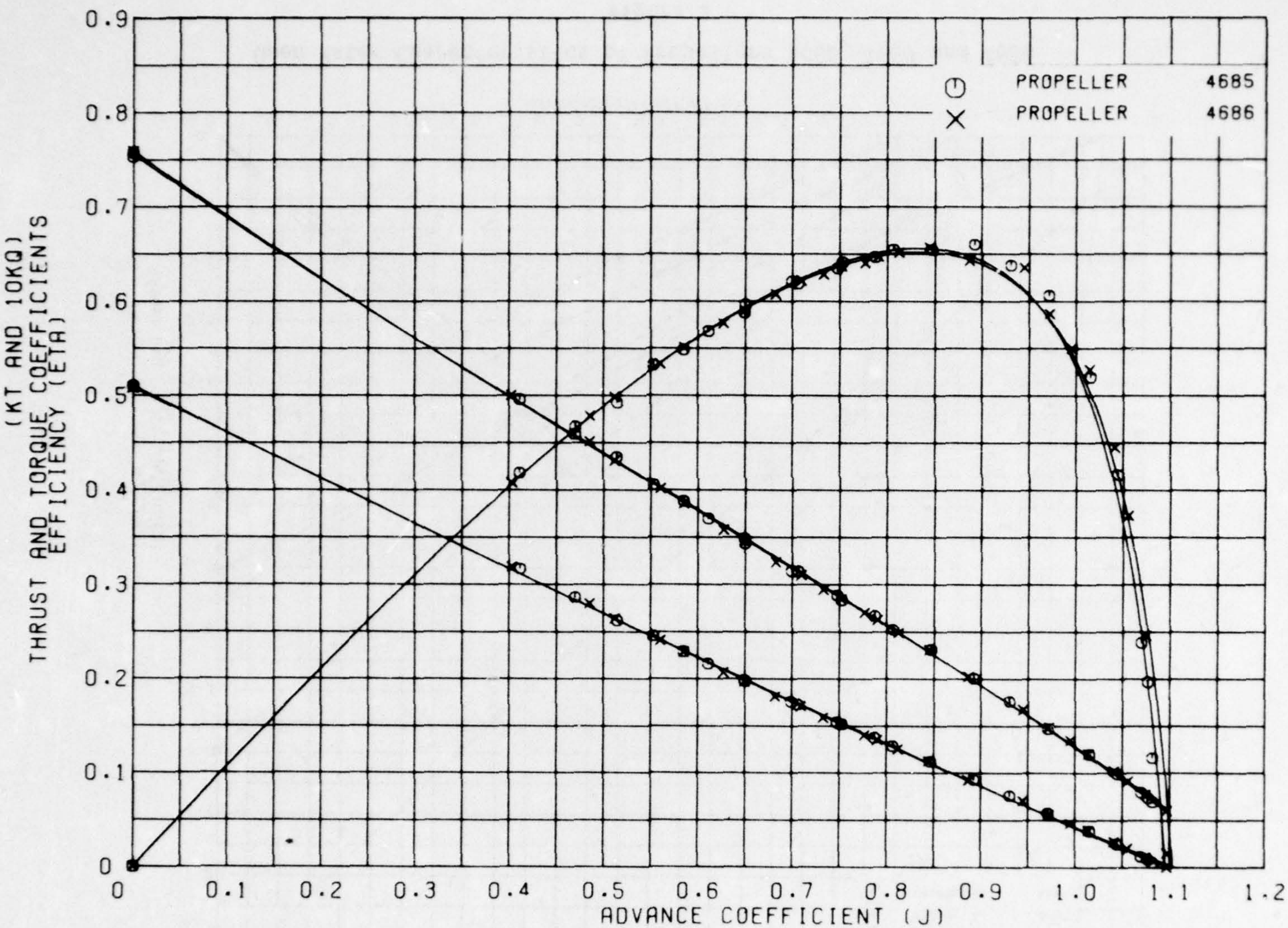
PROPELLER NUMBER =4688 PITCH RATIO = 1.300 SIGMA = .5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.8000	.0609	.1975	.3926	.0951	.0386	.0165	.0584	.0408
.8500	.0667	.2015	.4479	.0923	.0328	.0166	.0649	.0431
.9000	.0762	.2217	.4925	.0941	.0304	.0180	.0717	.0485
.9500	.0862	.2478	.5261	.0955	.0289	.0199	.0786	.0540
1.0000	.0942	.2718	.5515	.0942	.0272	.0213	.0856	.0580
1.0500	.0983	.2878	.5706	.0891	.0249	.0222	.0928	.0595
1.1000	.0973	.2920	.5834	.0804	.0219	.0221	.1000	.0578
1.1500	.0908	.2826	.5880	.0686	.0186	.0210	.1073	.0538
1.2000	.0789	.2600	.5793	.0548	.0150	.0198	.1146	.0452
1.2500	.0624	.2268	.5475	.0399	.0116	.0162	.1220	.0351
1.3000	.0430	.1877	.4736	.0254	.0085	.0132	.1294	.0237
1.3500	.0227	.1493	.3266	.0125	.0061	.0103	.1368	.0122
1.4000	.0045	.1206	.0832	.0023	.0044	.0081	.1441	.0024



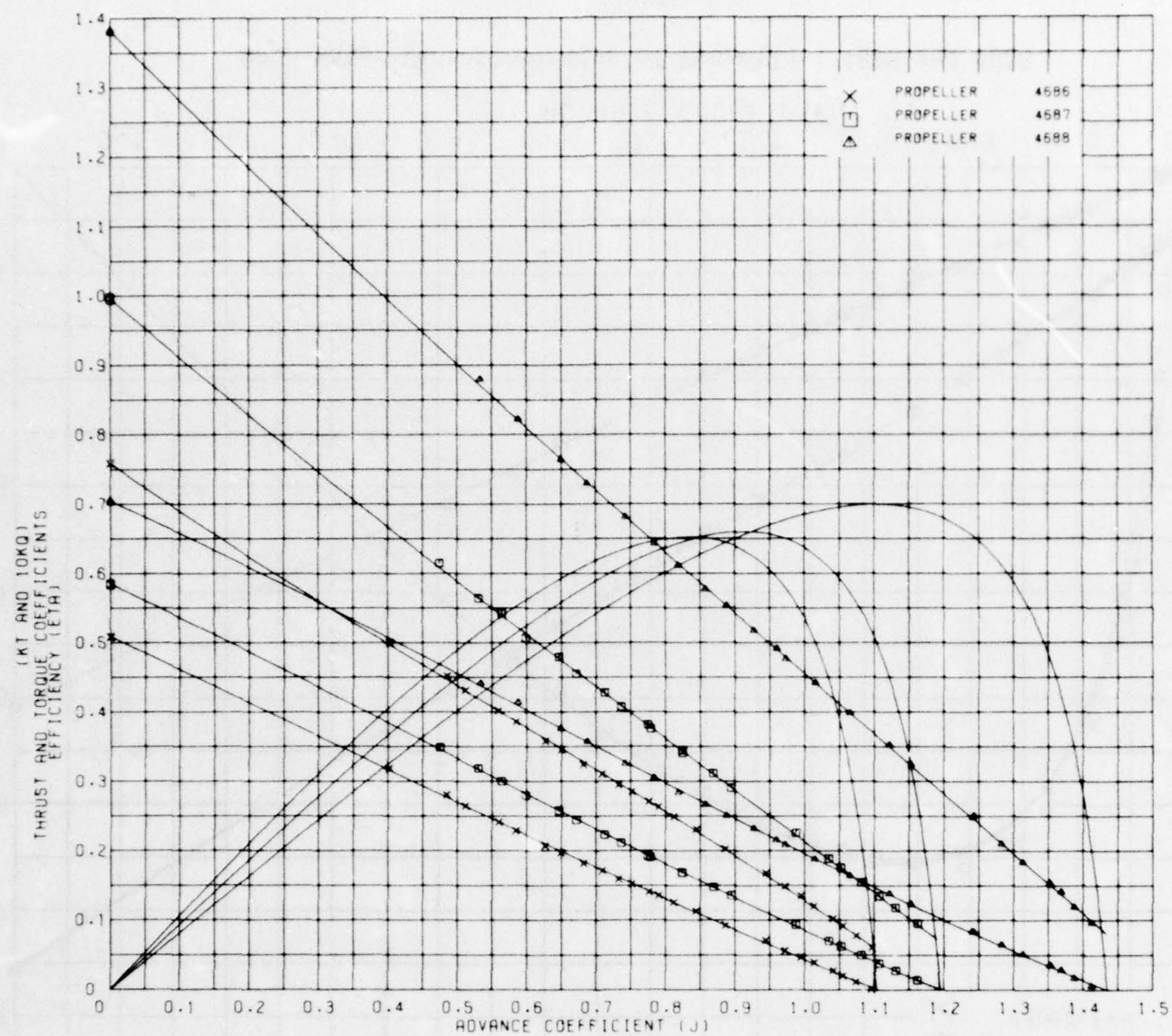
Photograph of a Commercial Propeller

Figure 1



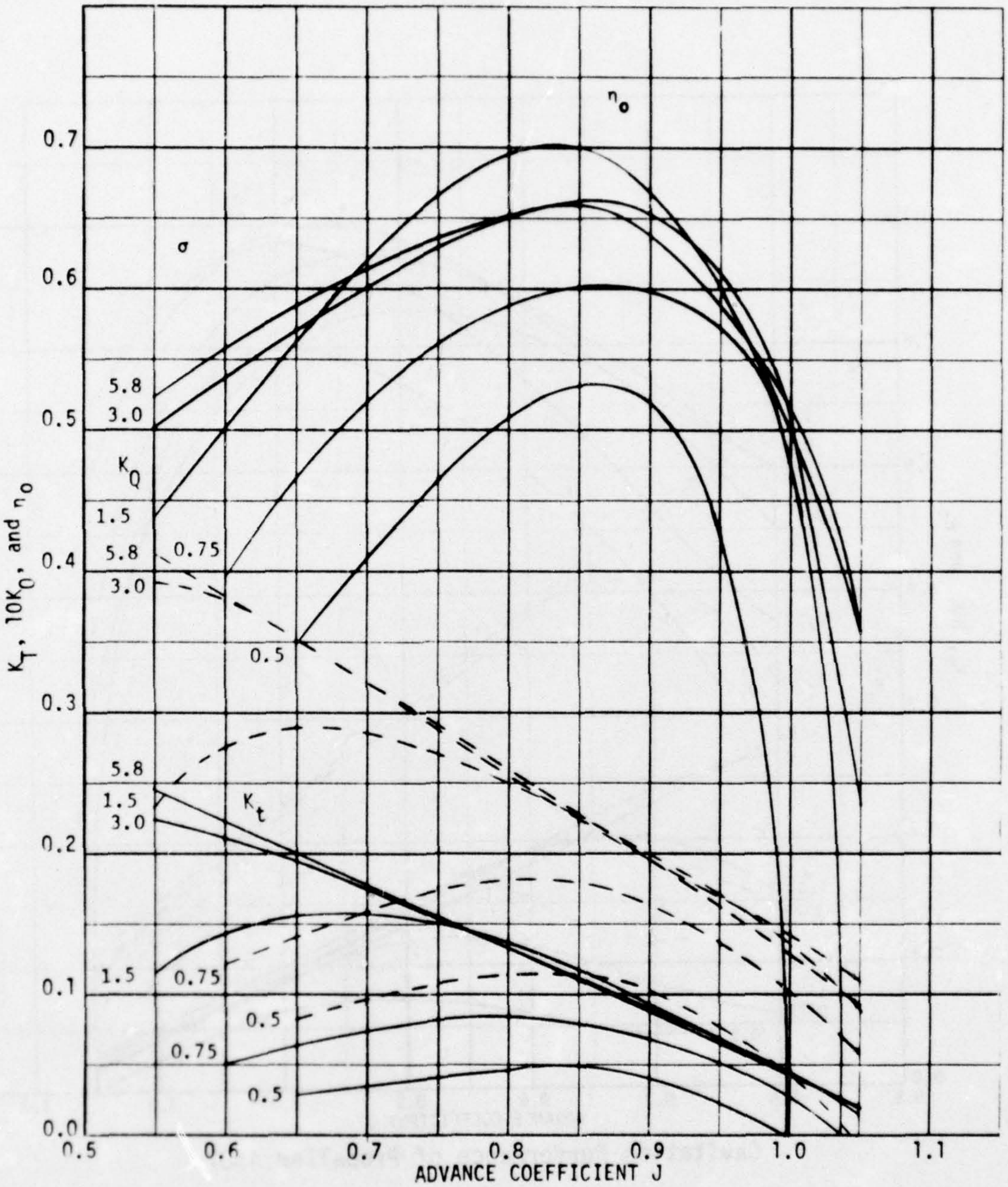
Open Water Characteristics of Propellers 4685 and 4686

Figure 2



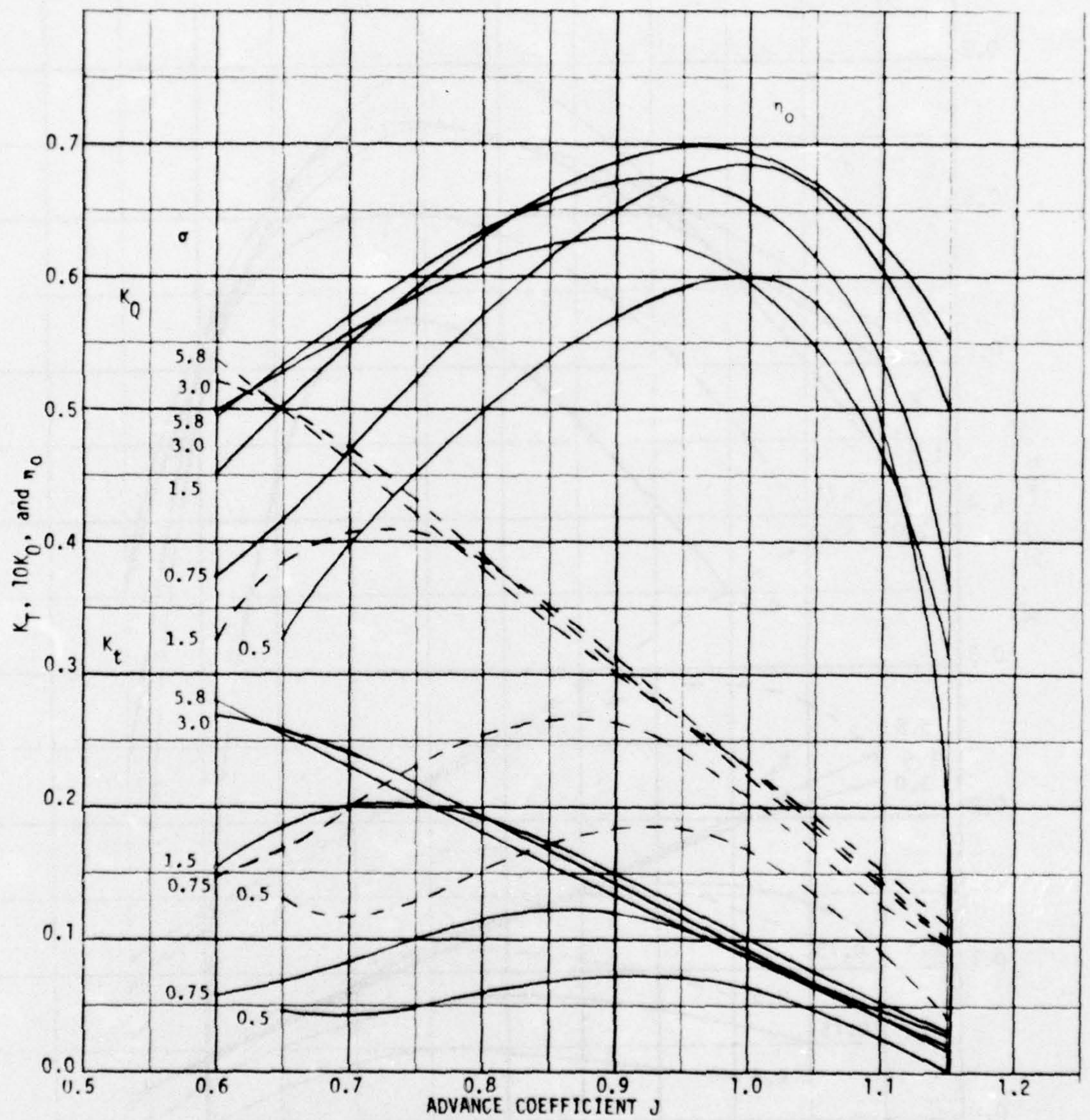
Open Water Characteristics of Propellers 4686, 4687 and 4688

Figure 3



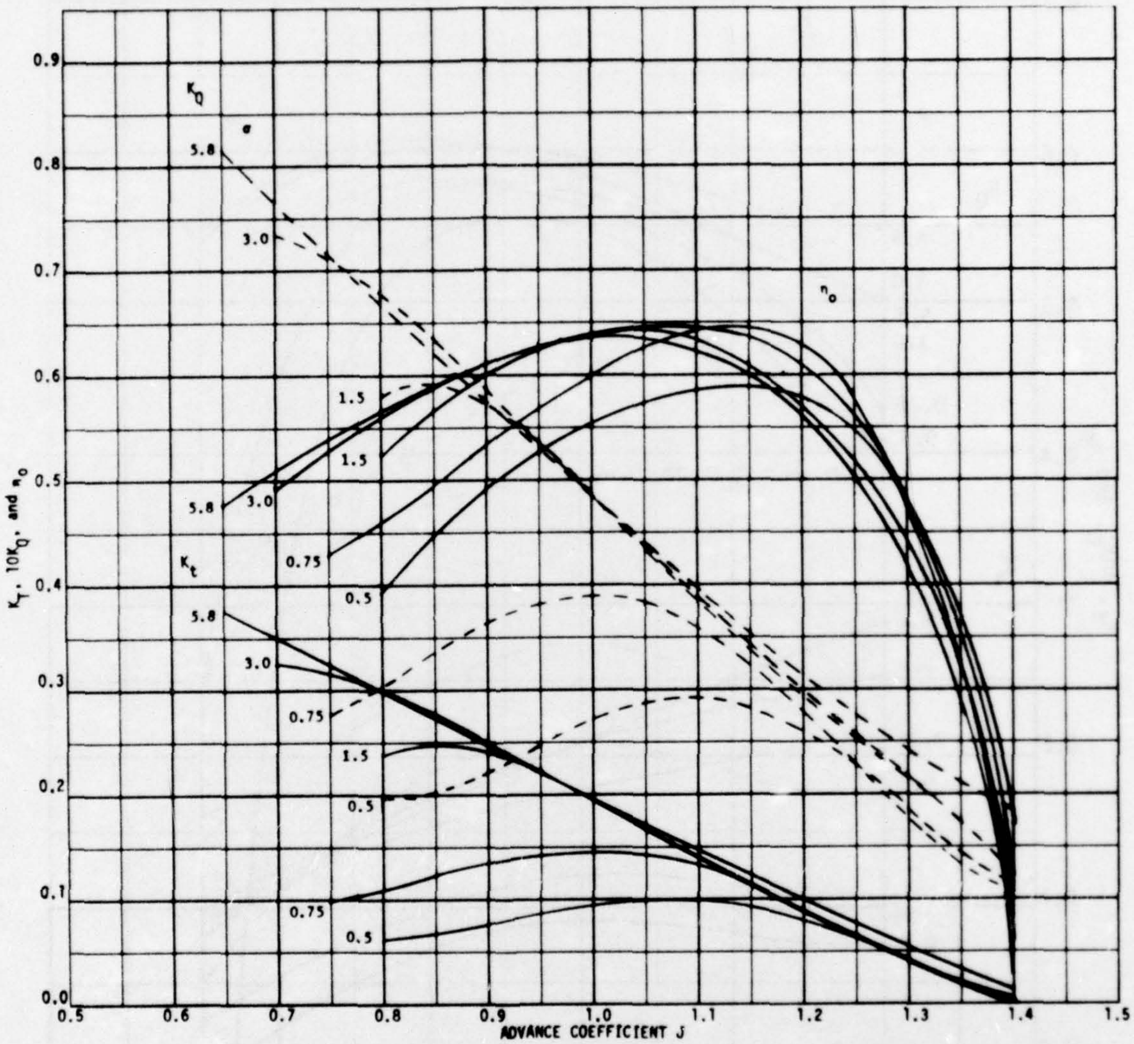
Cavitation Performance of Propeller 4686

Figure 4



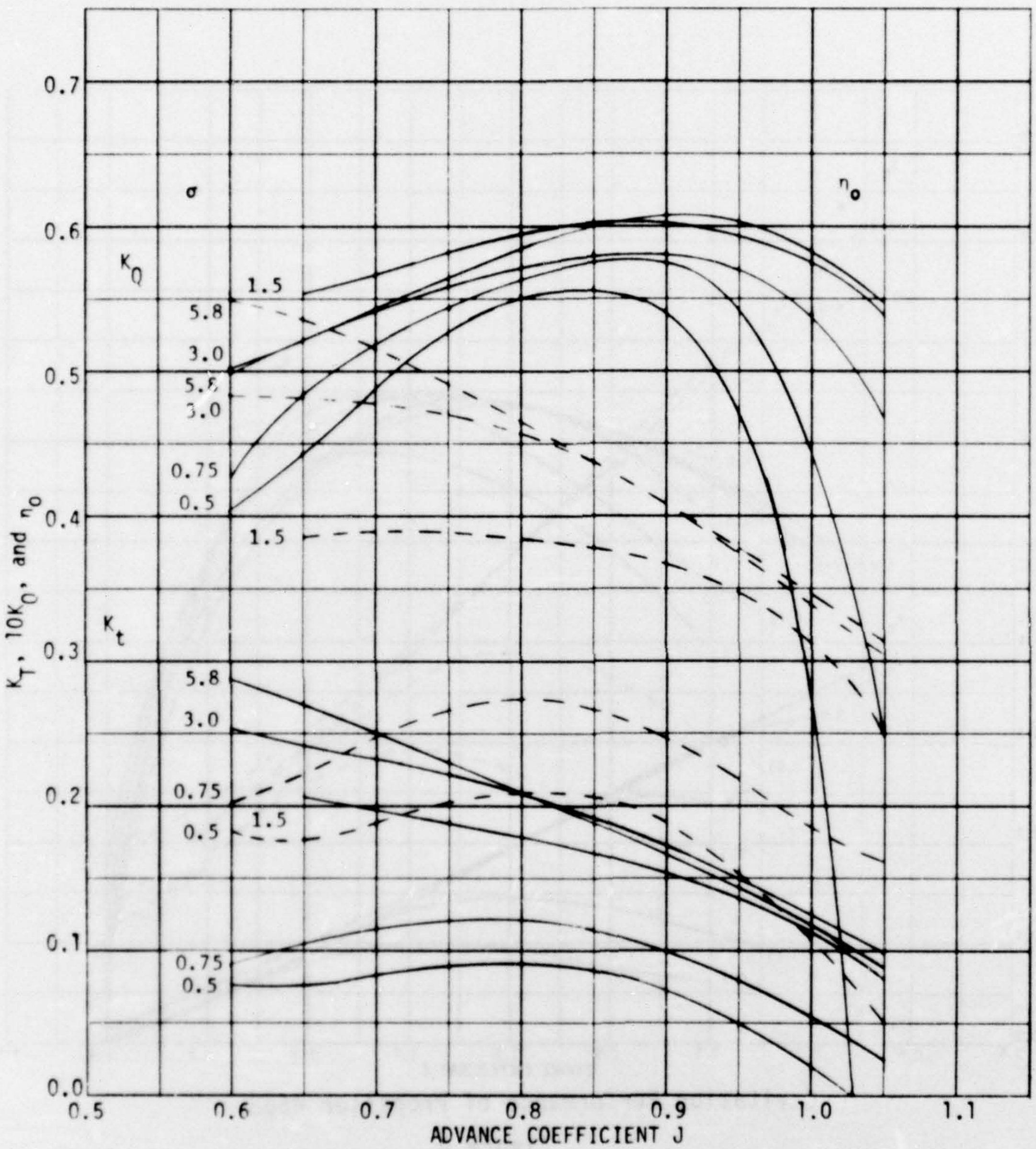
Cavitation Performance of Propeller 4687

Figure 5



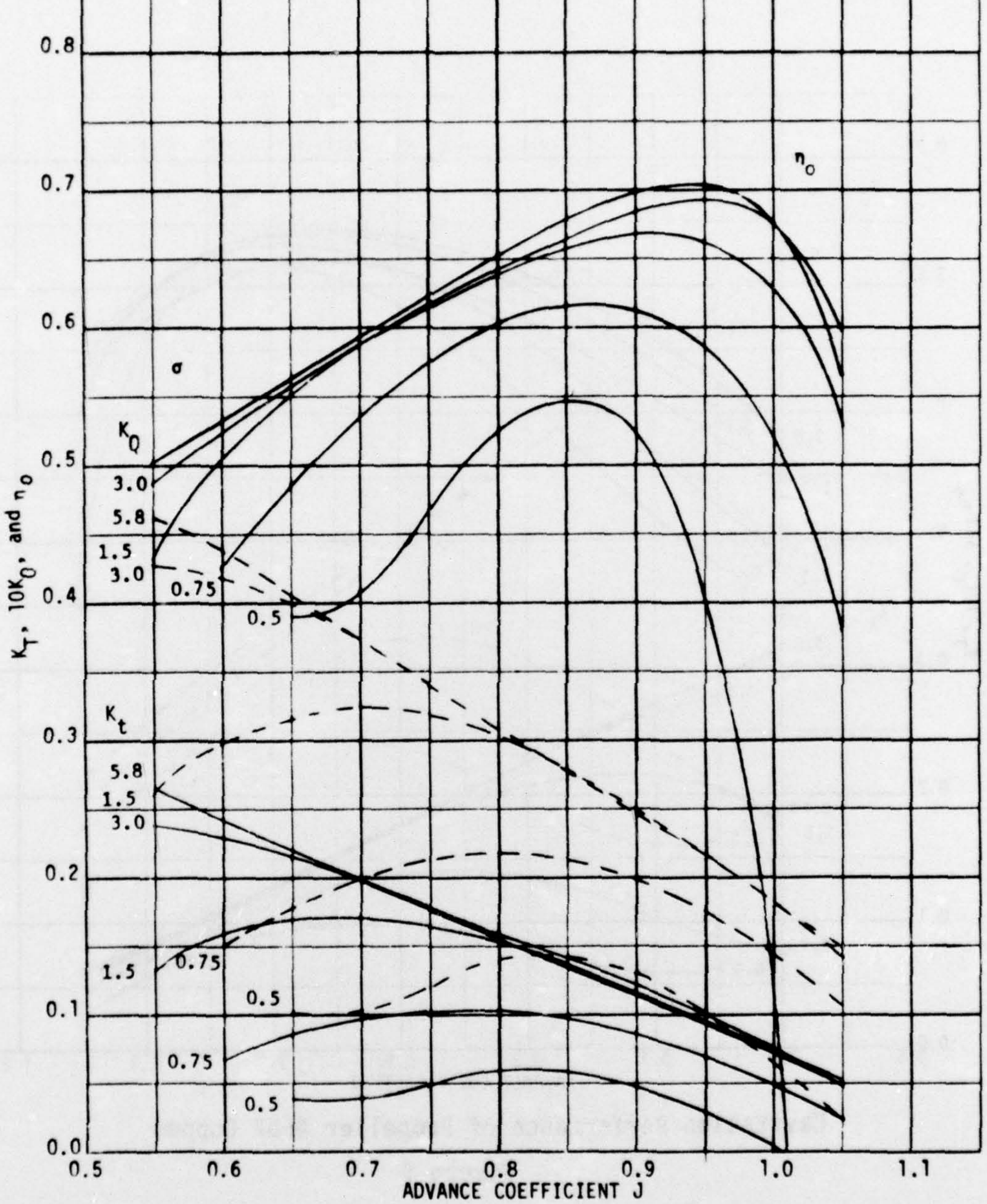
Cavitation Performance of Propeller 4688

Figure 6



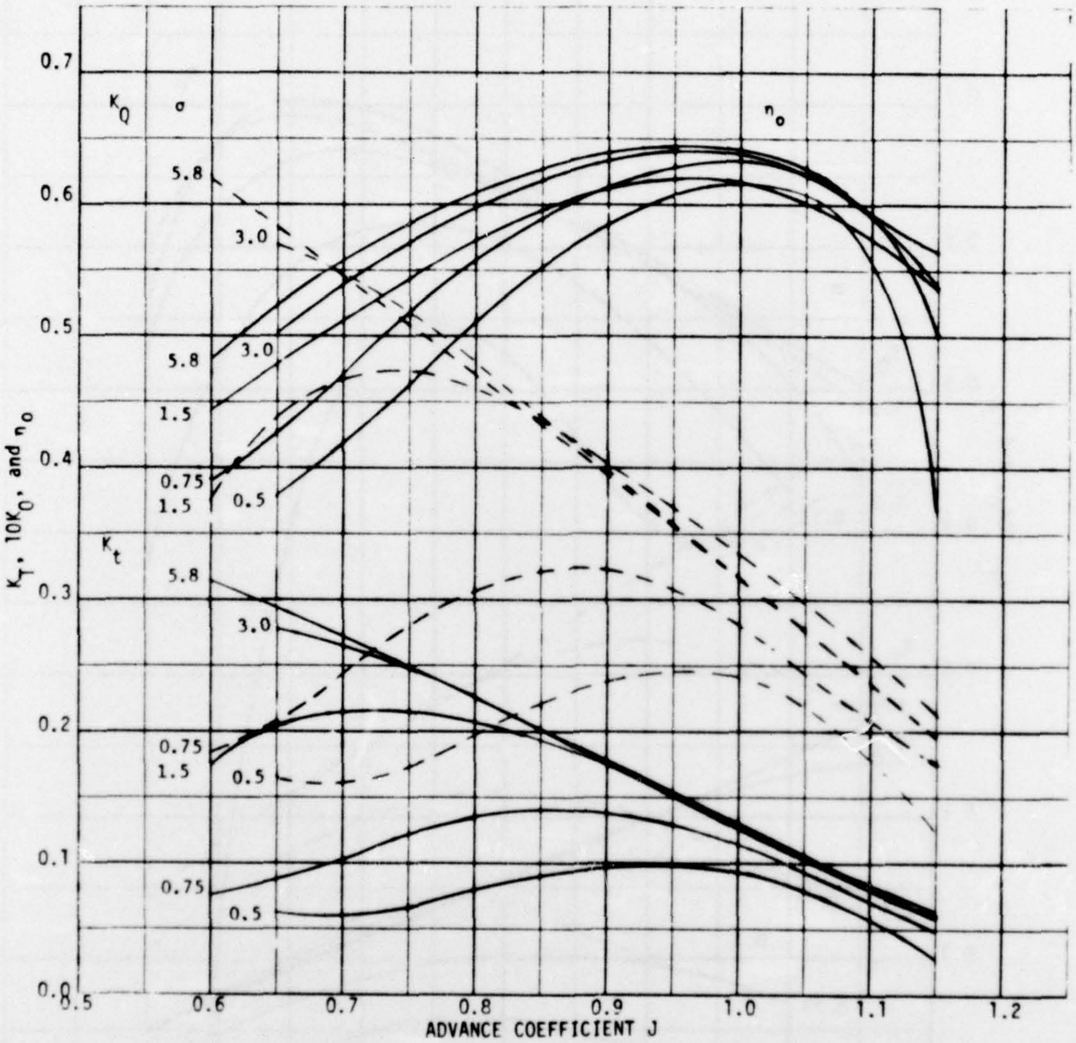
Cavitation Performance of Propeller 4685 Cupped

Figure 7



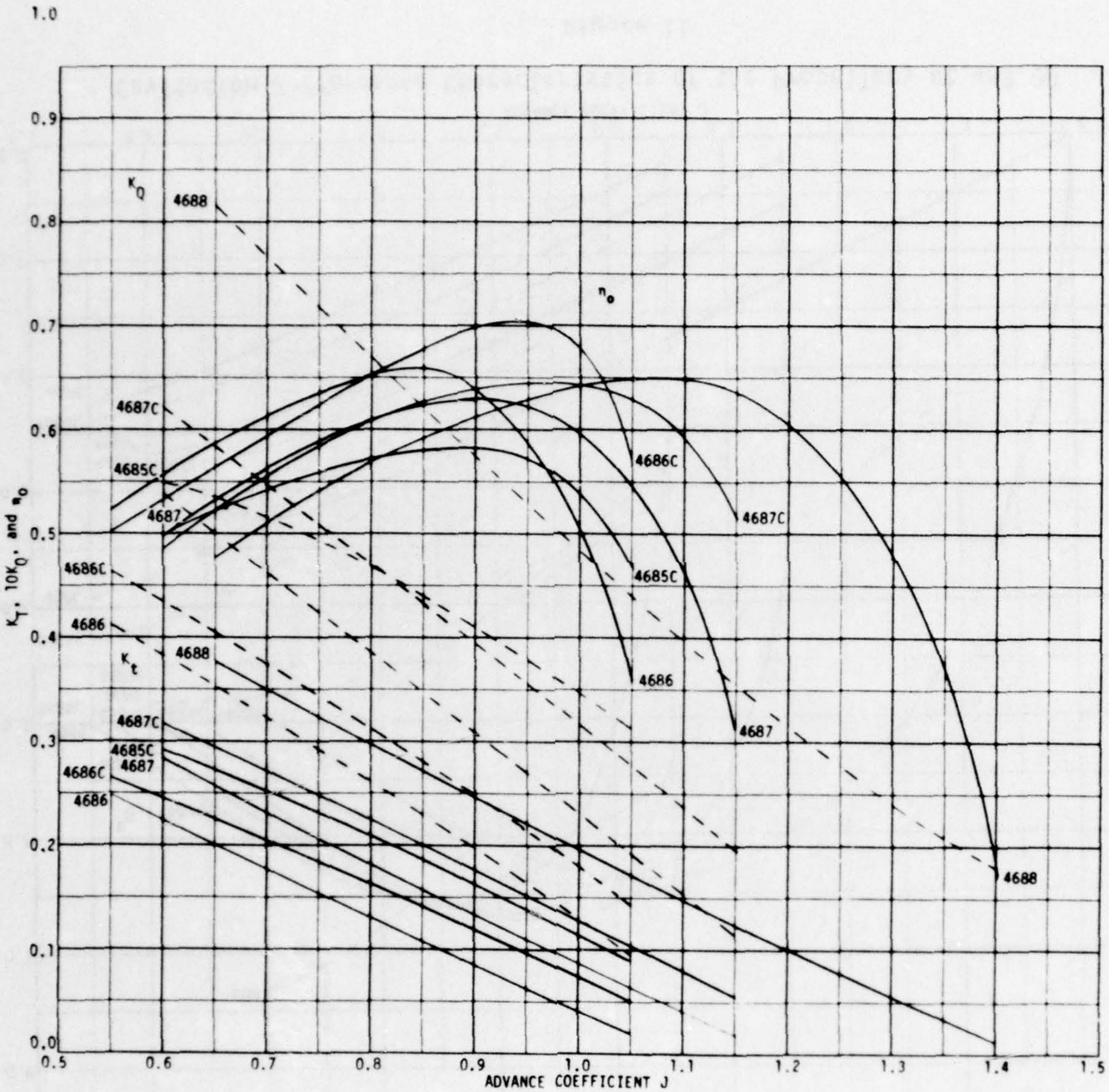
Cavitation Performance of Propeller 4686 Cupped

Figure 8



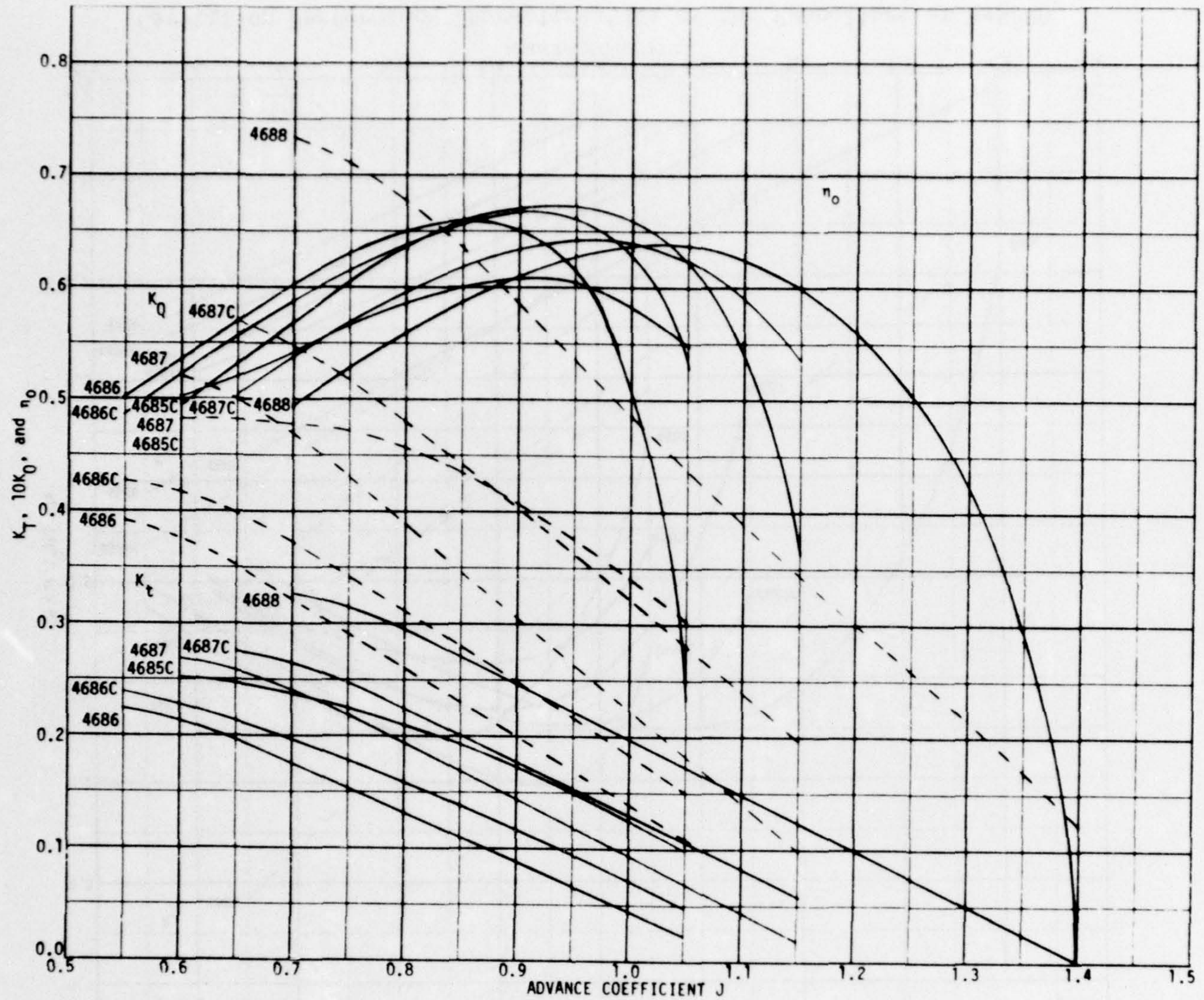
Cavitation Performance of Propeller 4687 Cupped

Figure 9



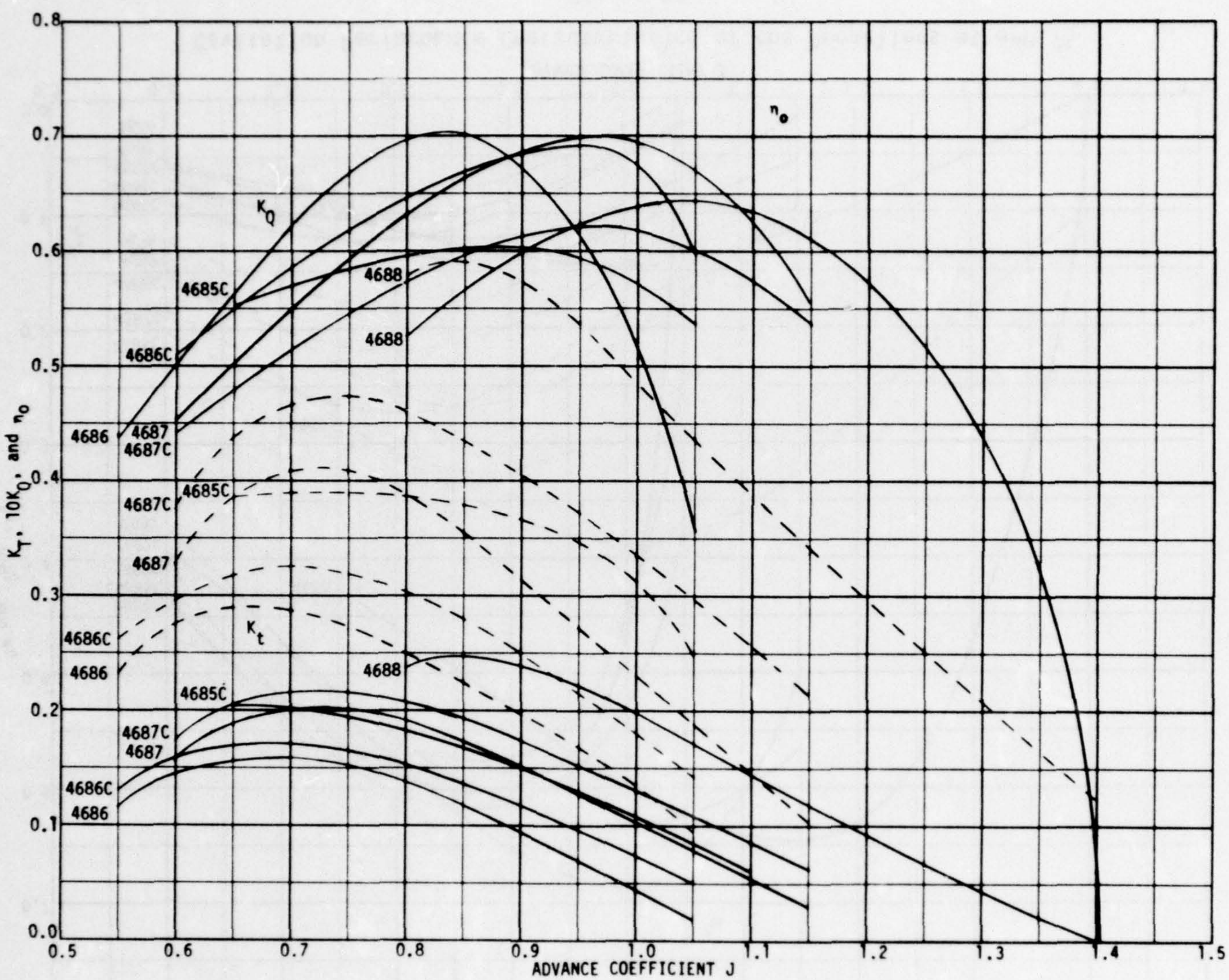
Cavitation Performance Characteristics of the Propellers at σ=5.80

Figure 10



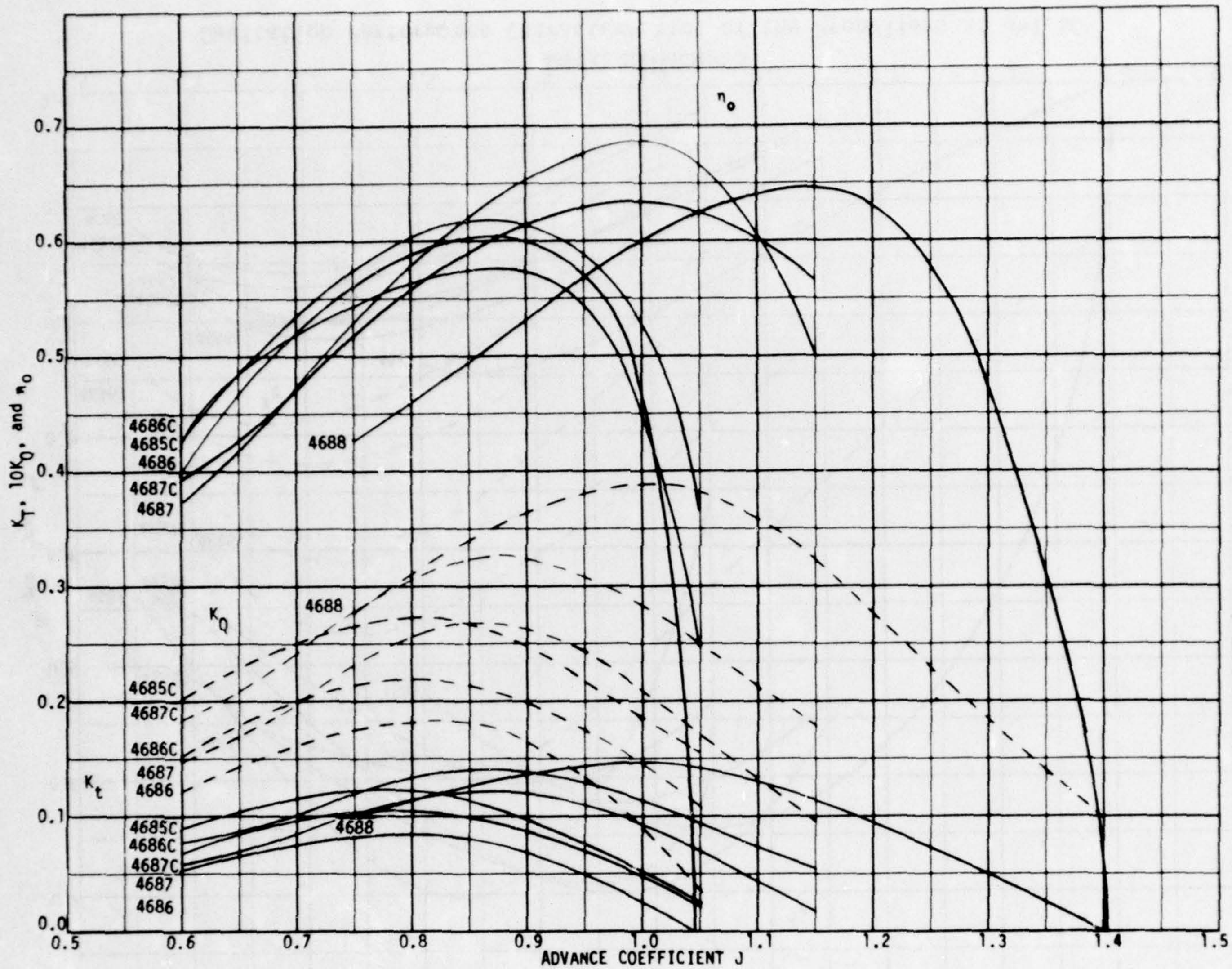
Cavitation Performance Characteristics of the Propellers at σ=3.00

Figure 11



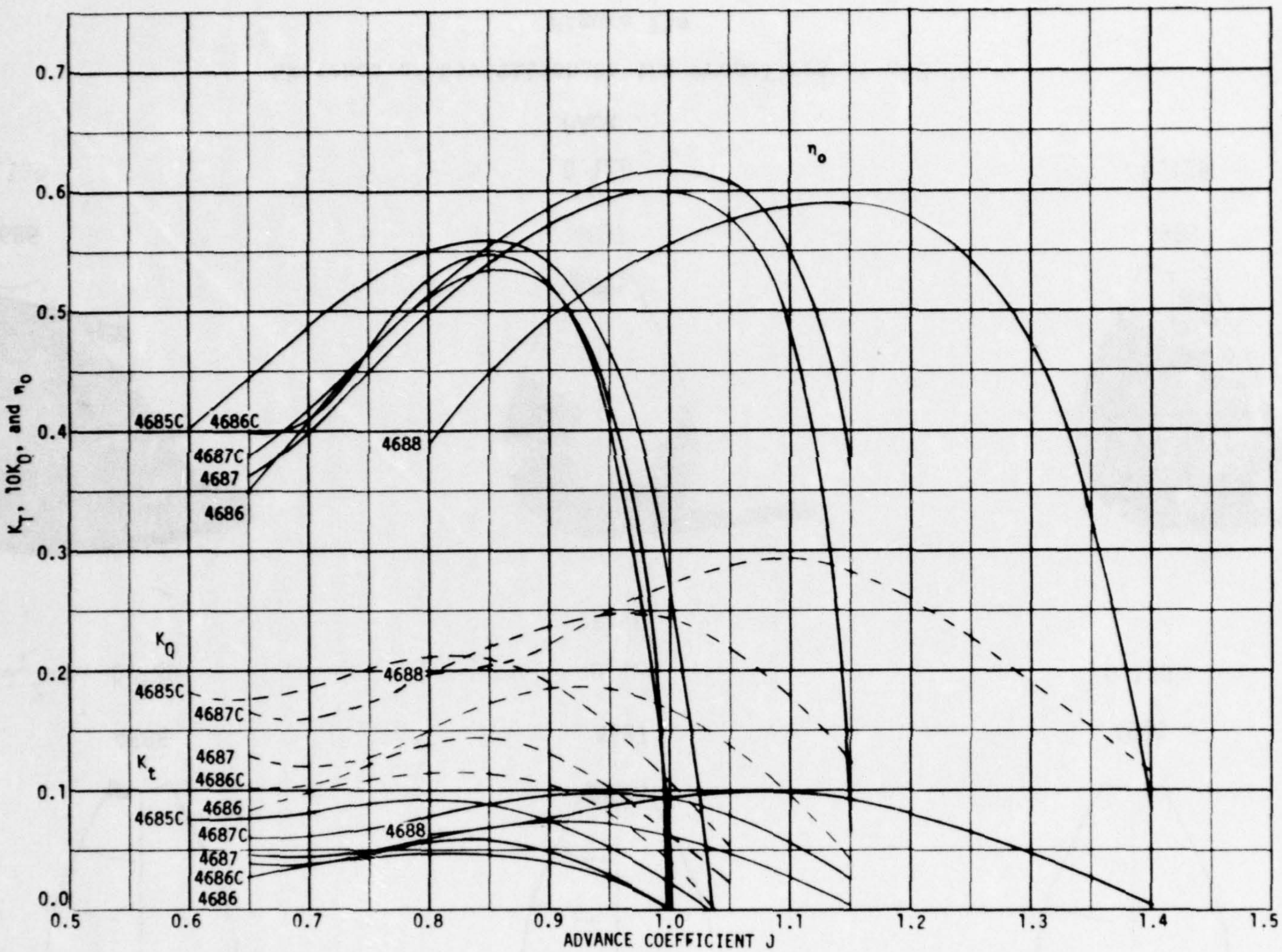
Cavitation Performance Characteristics of the Propellers at σ=1.50

Figure 12



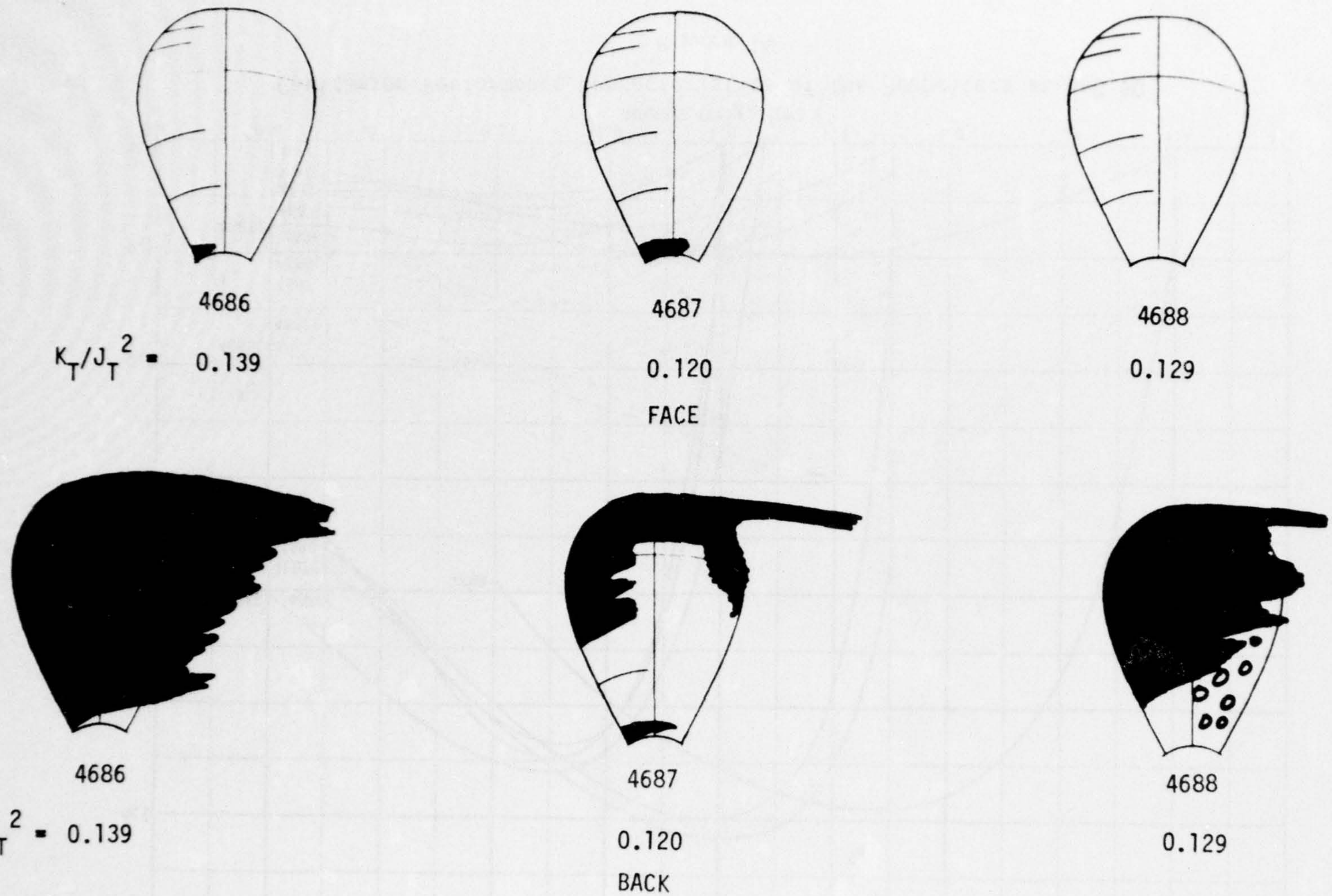
Cavitation Performance Characteristics of the Propellers at σ=0.75

Figure 13



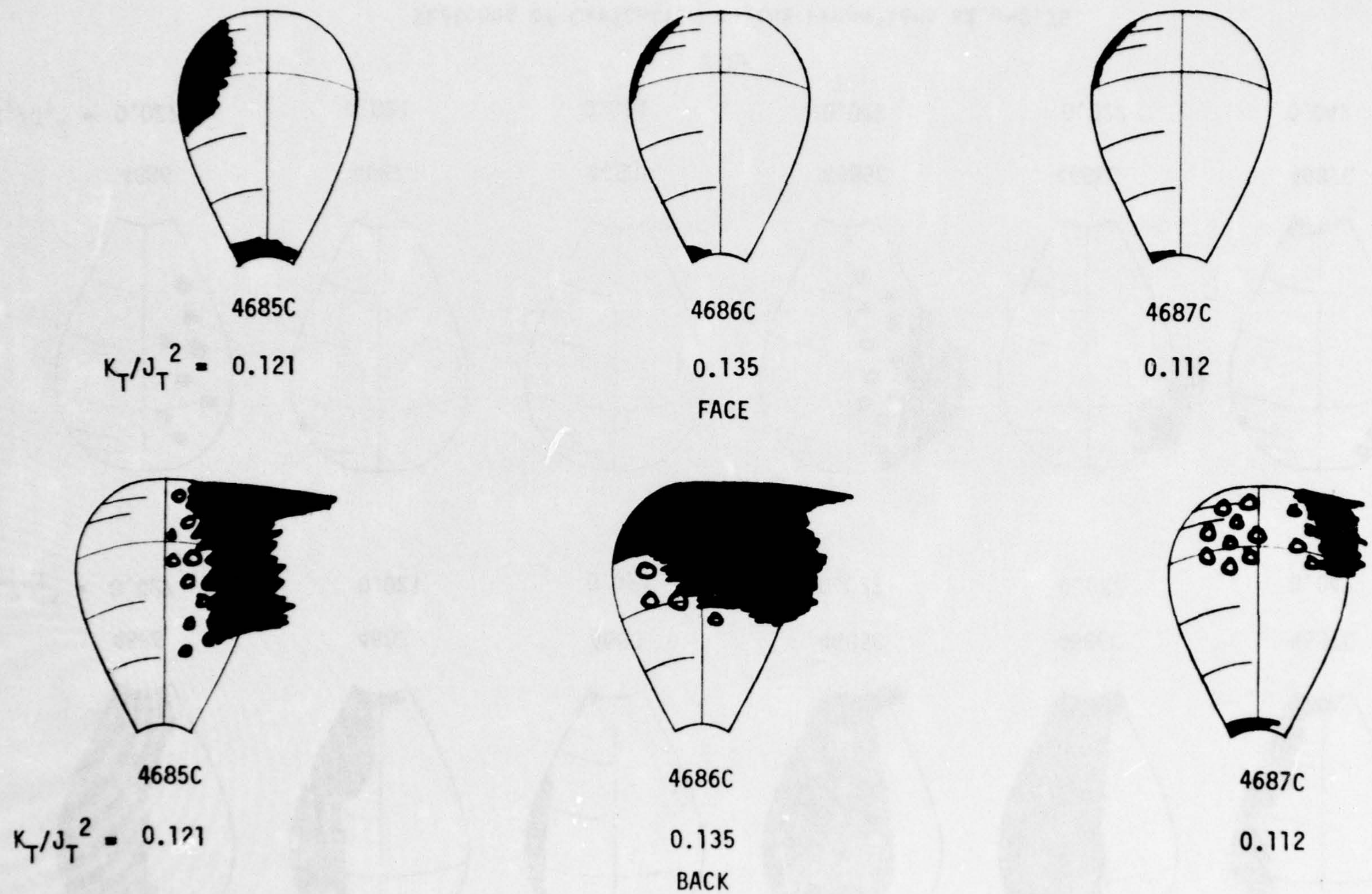
Cavitation Performance Characteristics of the Propellers at σ=0.50

Figure 14



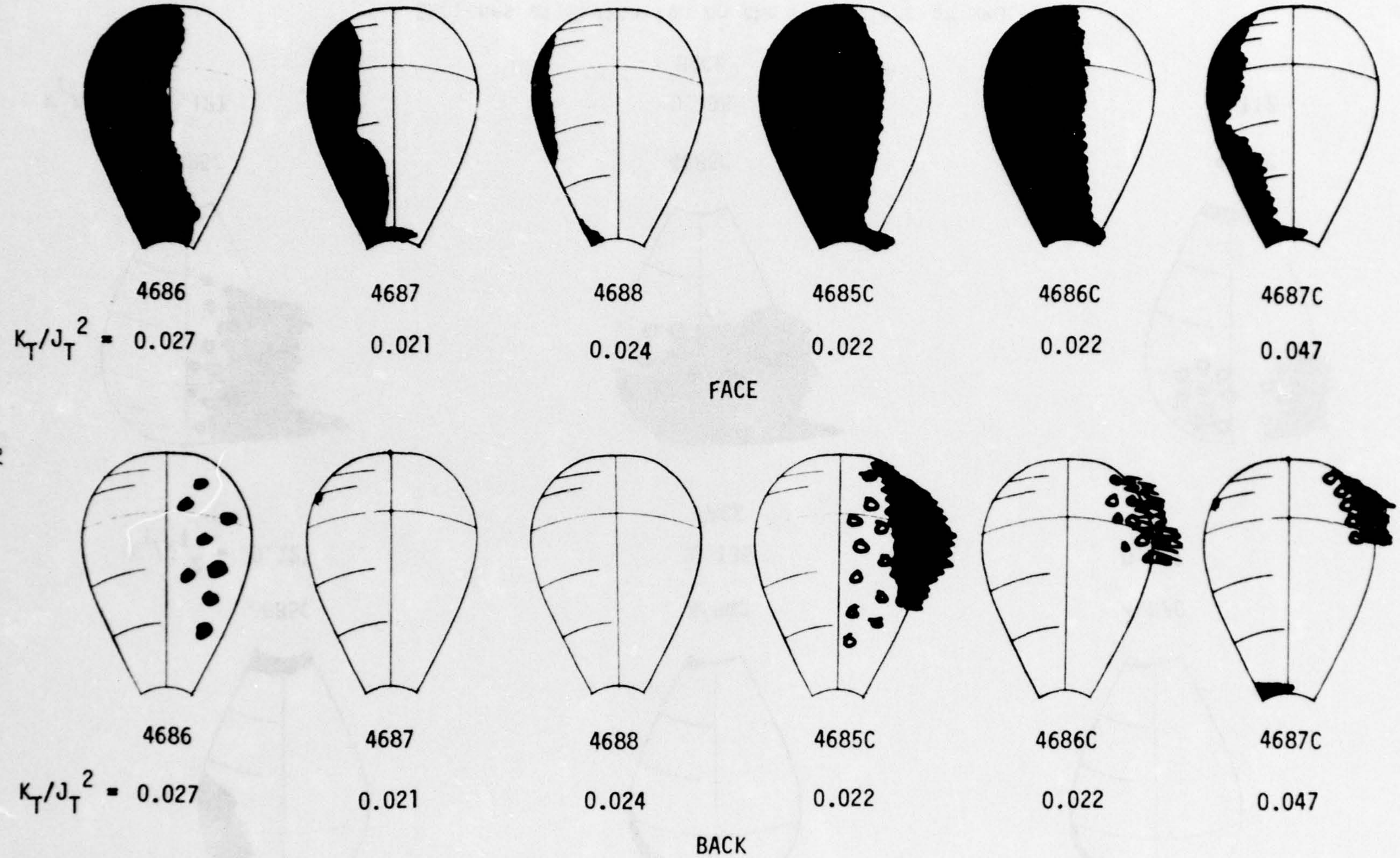
Sketches of Cavitation on the Propellers at σ=0.75

Figure 15a



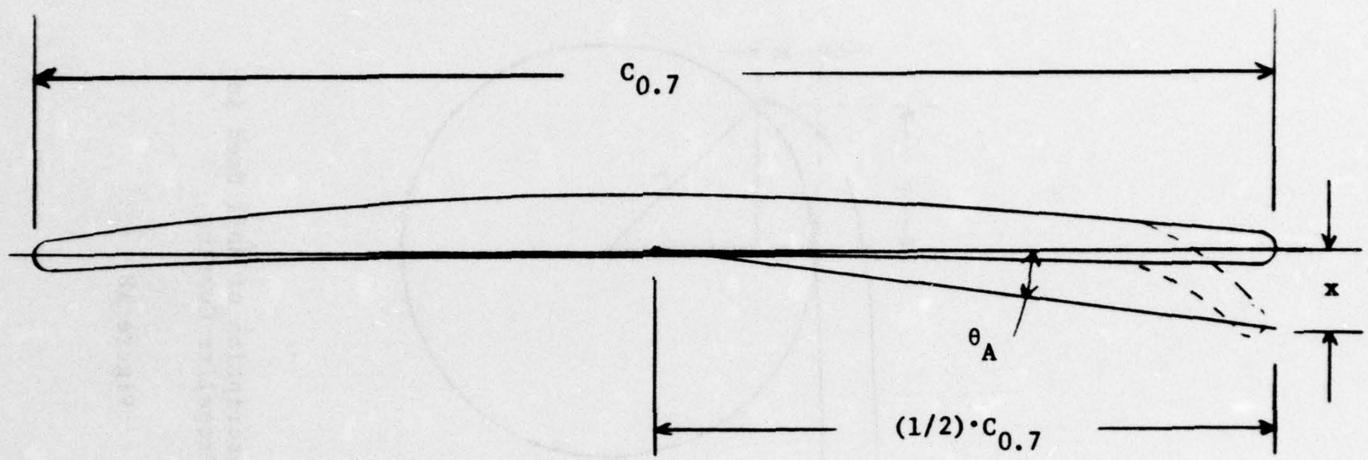
Sketches of Cavitation on the Propellers at $\sigma = 0.75$

Figure 15b



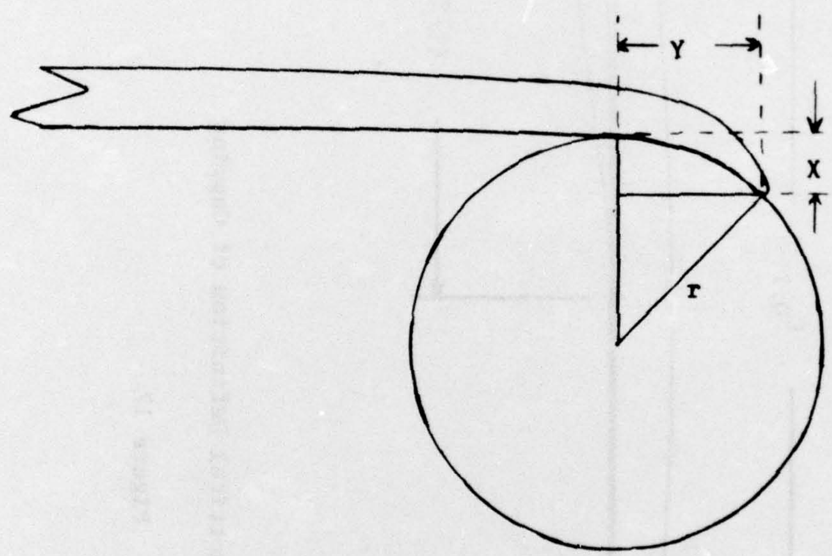
Sketches of Cavitation on the Propellers at σ=0.75

Figure 16



Geometrical Definition of Cupping

Figure 17



Geometrical Description of Ball Used in Propeller Cupping

Figure 18

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